

The HyWays-IPHE Project

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Hydrogen Technical Advisory Committee Meeting
November 7, 2008

Outline

- Project scope, objectives and participants
- Hydrogen pathway comparison
- Comparison of socio-economic modeling and vehicle modeling
- Dissemination

Project Scope and Objectives

- Compare roadmapping and system analysis activities in Europe and USA (and other IPHE countries)
- Improve understanding about roadmapping activities (common language, mutual understanding, alignment of international approaches)
- Institutional and personal exchange under IPHE patronage

HyWays-IPHE Partners

EU Institutes



Ludwig-Bölkow-
Systemtechnik



Fraunhofer
Institute
Systems and
Innovation Research



Institute for Energy
EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre



INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

U.S. Institutes



Industry monitoring group



DAIMLER



GE
Oil & Gas



What is a Roadmap?

The HyWays-IPHE consortium's understanding of a hydrogen energy roadmap is:

- A **joint endeavor** of industry, government, academia and the public, providing a structured process for a coordinated, long-term public and private effort in preparing, introducing and implementing hydrogen in the energy and transport system.
 - An **instrument for identifying the key technologies, products and markets, and foreseeable obstacles** to their development, introduction, and use, and the possible measures to overcome them.
 - An **assessment of expected impacts** on the market, society, and environment.
 - A **navigation tool** for strategic planning and implementation of research development, structural change and infrastructural investment.
 - An **opportunity for communication** between all involved stakeholders of different backgrounds, viewpoints, and interests in developing hydrogen (from its production, delivery, storage, dispensing to its application in final end-use).
- Based on a combination of visions pathway scenarios and systems modeling, it typically provides **a technical, economic and strategic analysis that may lead to a master plan** with a derived list of actions.

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- Project scope, objectives and participants
- **Hydrogen pathway comparison**
- Comparison of socio-economic modeling and vehicle modeling
- Dissemination

- We compared costs, energy use and GHG emissions of 9 Well-To-Tank (WTT) pathways
 - Pathways chosen because both parties had models that could be used and a suite of comparisons could be made
 - The set chosen is NOT a recommendation of the pathways that best fit into the hydrogen economy
- Tools:
 - E3database (used for HyWays project)
 - H2A Production / HDSAM / GREET / linked via the MSM

Pathways Compared

Nº	Timeframe	Production	Delivery	End use
1	Near term (~2007)	Onsite SMR	n.a.	Fueling station
2		Onsite Electrolysis		
3		Central Biomass	GH ₂ pipe	
4	Mid term (~2015)	NG SMR	LH ₂ truck	Fueling station
5		NG SMR	GH ₂ pipe	
6		Wind electrolysis		
7		Coal gasificat. w/CCS		
8	Long term (~2030)	NG SMR w/CCS	GH ₂ pipe	Fueling station
9		Coal gasificat. w/ CCS electricity byproduct	LH ₂ truck	

Pathway Comparisons

- Nine pathways were compared in this project but this presentation will focus only on pathway #3
- Production, delivery, and pathway costs were compared
- WTT & WTW energy use and GHG emissions were compared
 - WTW not reported due to differences in vehicle fuel economy assumptions
- Information on all the pathways is available in the WP2 report (on the website)

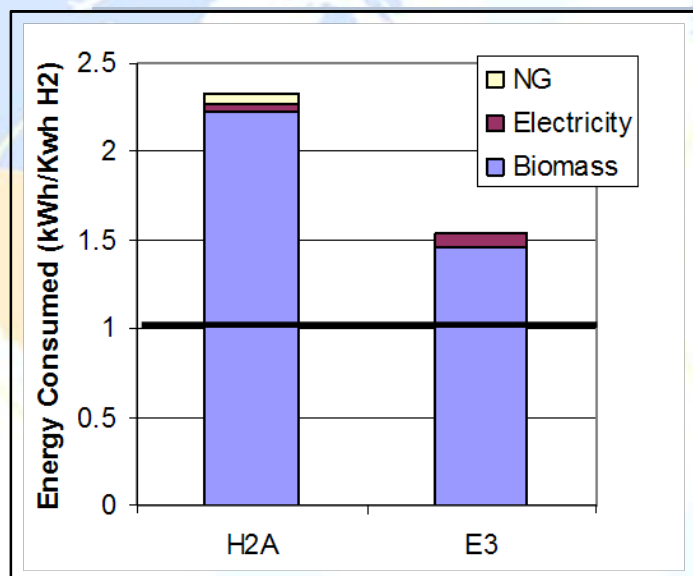
Financial Parameter Comparison

	H2A	E3database	Selected Parameters
Financing	100% Equity @ 10% DCFROR	100% Debt @ 8% Interest	100% Debt @ 8% Interest
Taxes	35% Federal 6% State	None	None
Working Capital	15%	0%	0%
Construction	1-4 years	0 years	0 years
Depreciation	MACRS as allowable by law	Straight Line over analysis period	Straight Line over analysis period
Analysis Period	20 to 40 years	17.5 to 25 years	20 y (1,2,3,6) 40 y (4,5,7,8,9)

A set of financial parameters was selected so that we could make comparisons that would be insignificant next to differences in financial parameters. The selected parameters are NOT a recommendation of financial parameters that should be used in future analyses.

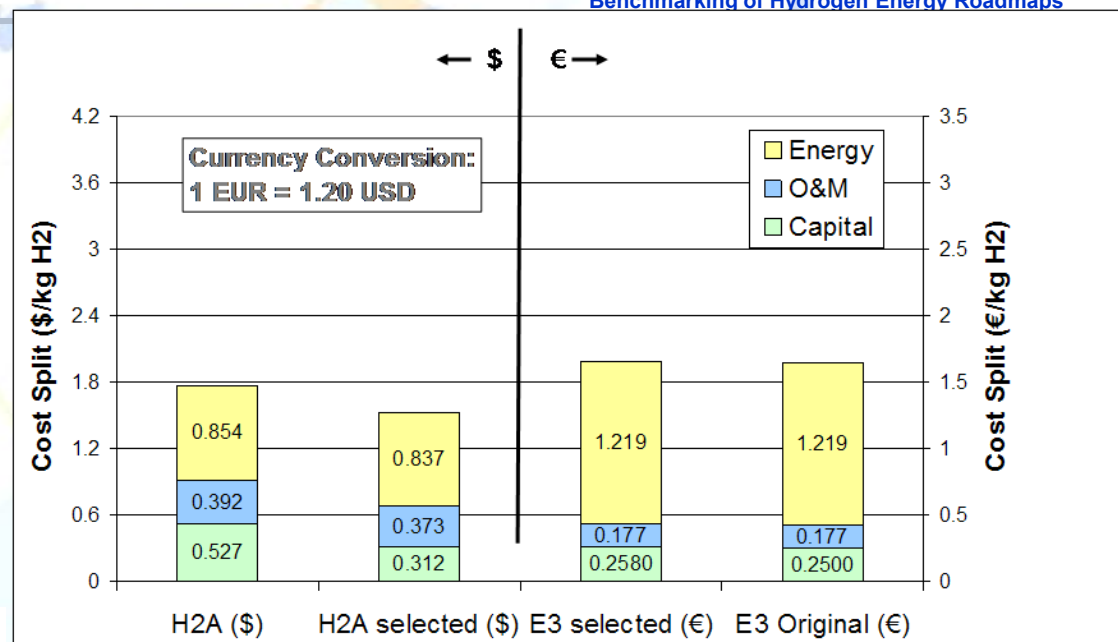
The project used the term “harmonized” instead of “selected” in its documentation

Pathway #3 Production Comparison



E3database has a higher gasification efficiency, higher PSA efficiency, and lower pressure H₂ product gas than H2A.

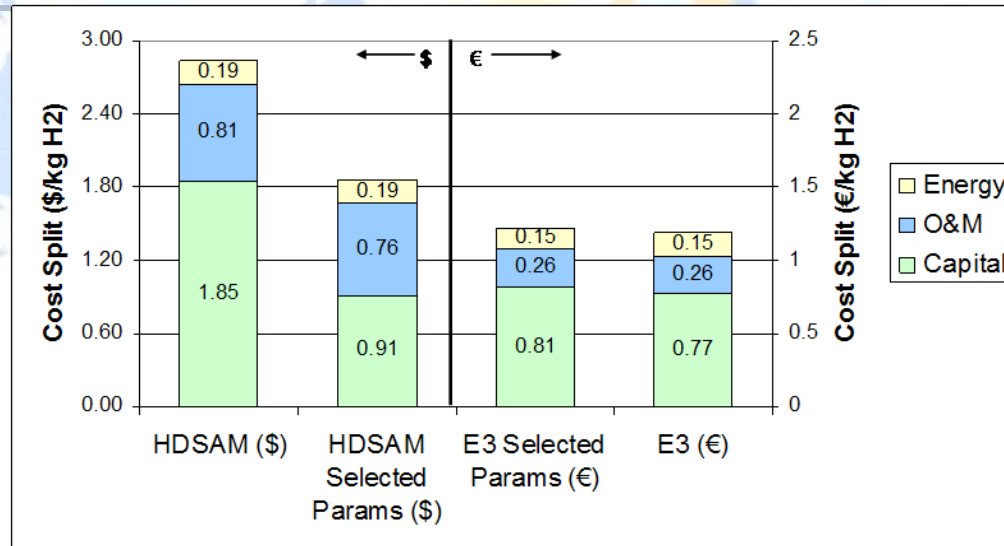
(overall efficiency of 65% vs. 46%)



Feedstock cost difference [H2A is \$46/dry ton & E3database is €87/dry ton (\$104)] leads to lower energy costs in H2A.

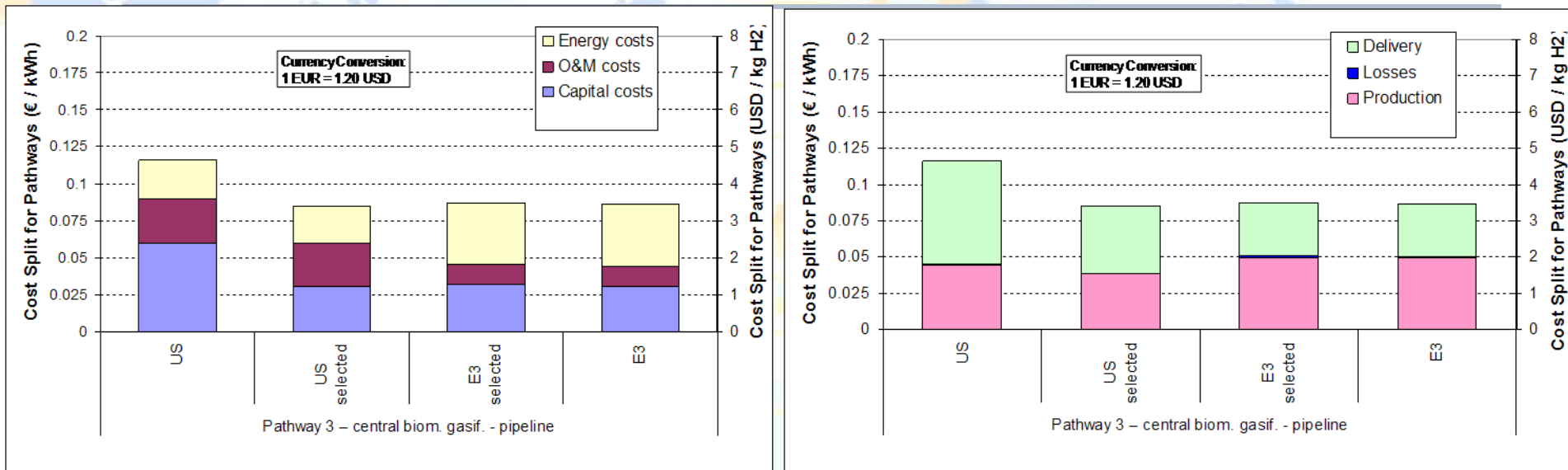
H2A assumes a larger staff and includes more operating costs than E3database leading to higher O&M costs

Pathway #3 Delivery Comparison



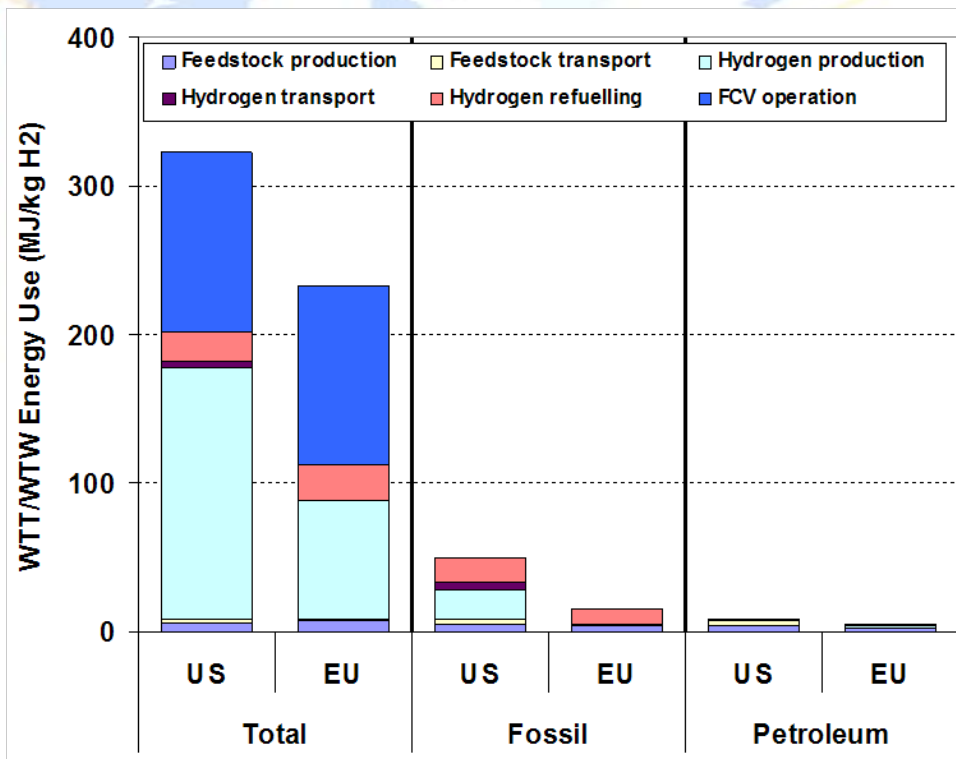
- HDSAM designs delivery scenarios with terminal storage; E3database has single pipelines and specific delivery volumes
- Energy costs are similar because of counter-acting differences
 - E3database has a higher dispensing pressure
 - HDSAM has energy for geologic storage and lower compressor efficiency
- HDSAM O&M costs are much higher than E3database
- E3database capital costs are higher than HDSAM because of the “learning-by-doing” methodology of reducing costs

Pathway #3 Cost Comparison



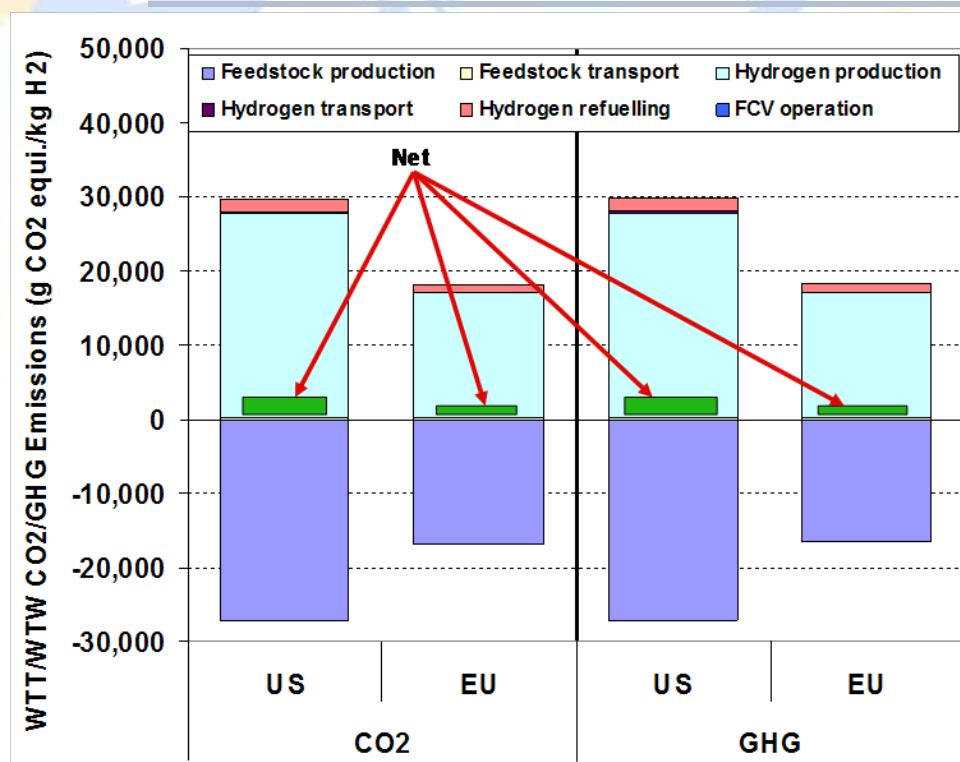
- Most of the pathway costs were similar when the selected financial parameters were used for this analysis
- The energy costs in Europe were almost always higher than those in the US.

Pathway #3 Energy Use Comparison



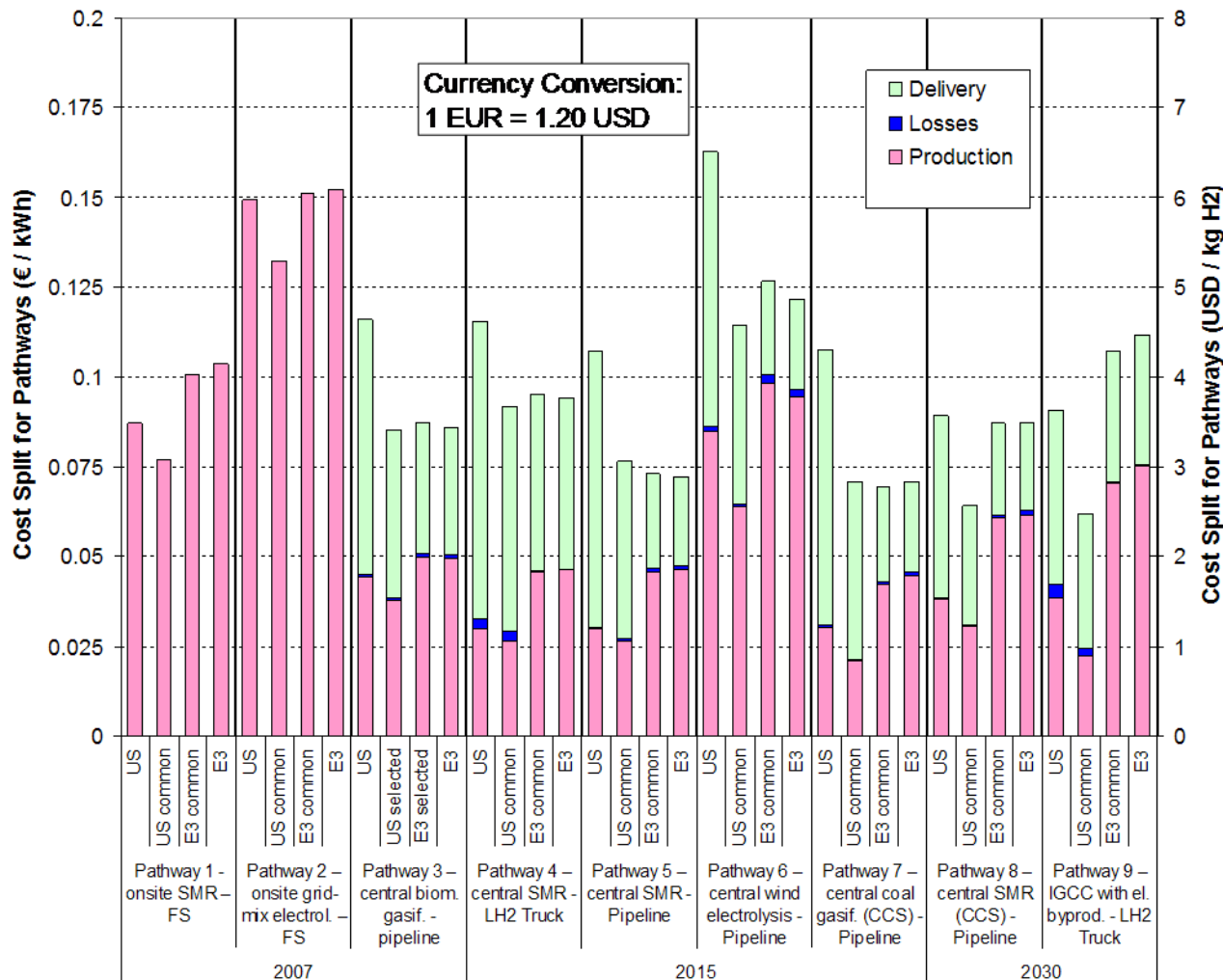
- The methodologies were similar although we used different terms and had to make the disaggregation methodology consistent.
- The US production efficiency is much lower leading to higher energy use.

Pathway #3 GHG Emission Comparison



- Again, the methodologies were similar although we used different terms and disaggregation methodologies.
- Hydrogen transport and distribution required more energy in the US analysis leading to higher emissions.
- For other pathways, variations in the electricity generation mix affected the results
 - Especially, in the electrolysis and coal with electricity byproduct pathways.

Pathway Cost Comparison



- Pathway cost, WTW energy, and emissions comparisons were made for all pathways.
- The selected set of financial parameters was used so that we could make comparisons that would be insignificant next to differences in financial parameters. The selected parameters are NOT a recommendation of financial parameters that should be used in future analyses.

General lessons learned from pathway comparison I

- Tools used by HyWays & US are consistent
- Modeling philosophies affect conclusions
 - US focuses on business cases, EU on policy support
 - Estimated vehicle fuel economy lower in the US than the EU
 - Cost reductions through time (EU: learning by doing, US: learning by technology development)
 - The US includes a full design of delivery scenarios, EU has a simplified design
 - The method of accounting for losses and emissions is different.
- Developing a common understanding and language is challenging
 - Terms often have different meanings to different people – e.g., Well-to-Tank (WTT) & Process fuel / feedstock

General lessons learned from pathway comparison II

- Financial parameters may be different from nation to nation
- There may also be significant differences in technical assumptions:
 - Energy price projections (higher on EU side)
 - Vehicle efficiency (higher on EU side)
 - Biomass gasification efficiency (higher on EU side)
 - Coal gasification efficiency (higher on US side)
 - Process and pathway configurations (e.g. pipeline delivery, compressor station, geologic storage)
 - Dispensing pressure (higher on EU side)
 - Emissions for coal production are much higher in the EU analyses
 - The US has higher liquid hydrogen losses than the EU
 - Estimating the effects of co-products for both so different methods are used

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- Project scope, objectives and participants
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- Comparison of socio-economic modeling and vehicle modeling
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Types of Models & Tools: Findings from U.S.-EU Comparison

LCA LIFE CYCLE ANALYSIS

KEY FINDINGS OF THE COMPARISON

Comparable assumptions and results. Regional differences (vehicle fuel economy, financial assumptions). Minor need for review.

CONCLUSIONS & RECOMMENDATIONS

Existing models are sufficient and reliable if adapted to regional particularities.

TEC TECHNOLOGY AND ENGINEERING COSTS

Technology cost projections comparable. Some differences identified (technology learning mechanisms). Cost decrease by technology learning is dependent on worldwide uptake.

Existing cost prediction models should be harmonized to uniform global uptake scenarios when making international comparisons.

HID REGIONAL HYDROGEN INFRASTRUCTURE DEVELOPMENT

Spatially explicit methods coupled with TEC models exist. H₂ production pathways differ by regions. EU technology mix more policy-driven and diverse than US least-cost mix.

Growing tool set. Expect H₂ production pathways to differ by region.

MT MARKET DEVELOPMENT AND TRANSITION

Consumer and demand analysis are key. Plausible market transitions seen are under policy and technology success. Focus so far on transport markets. US and EU methods both combine a variety of tools.

Combined-model approach will be needed. Include H₂ stationary markets.

ESM ENERGY SYSTEM MODELLING

H₂ only one component of large integrated model. System-wide approach reveals inter-sectoral tradeoffs, e.g. for GHGs and fuel costs. Long-run energy price projections differ.

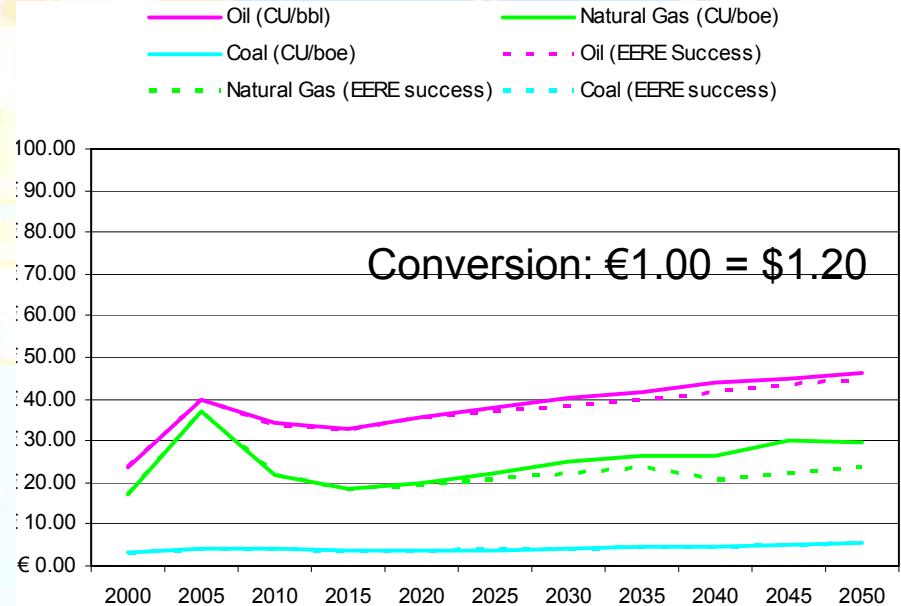
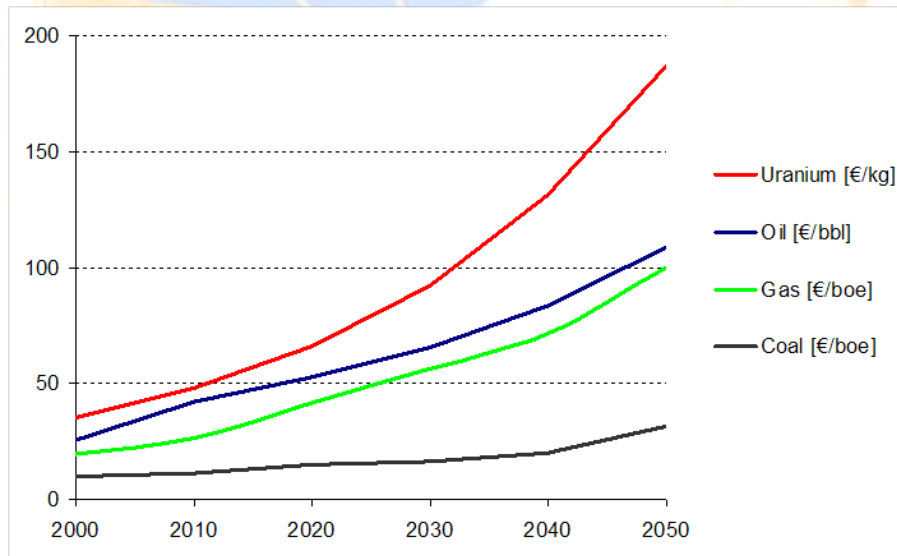
Coupling to MT and HID models is important as is use of consistent energy supply costs and world energy markets for international comparisons.

Comparison of Energy Prices

Prices of Energy Supplies

HyWays

US Markal



Exogenous source

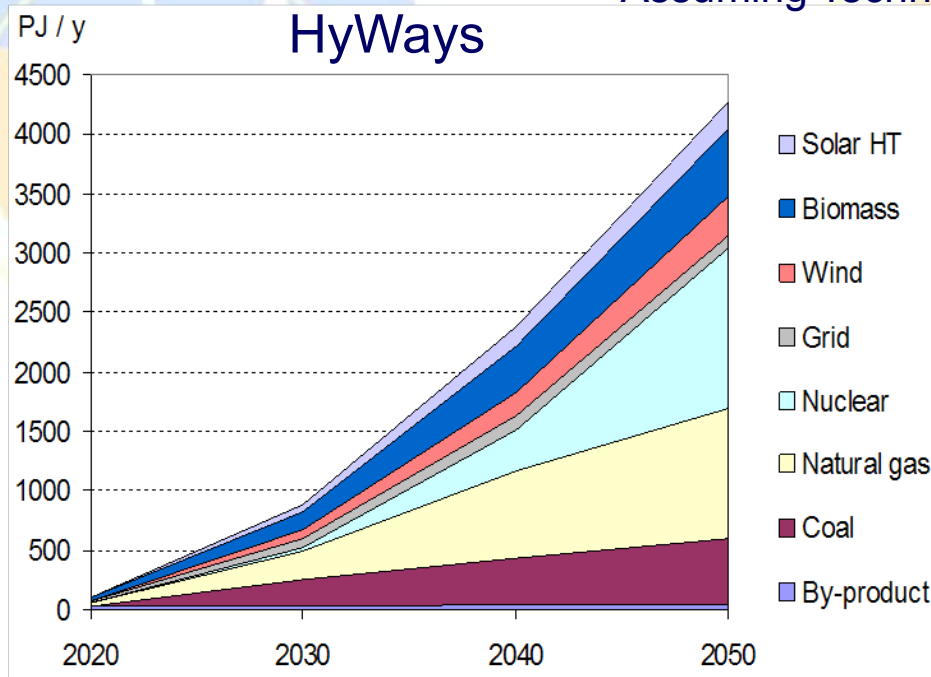
Endogenous Calculation

- ⇒ Consistent energy supply costs are important for project selection. Changing them too often will cause too much disruption of projects that should be selected.
- ⇒ External drivers (i.e., world markets) are important but difficult to consider in a regional model.

Comparison of Production-Technology Mixes HyWays - IPHE

Benchmarking of Hydrogen Energy Roadmaps

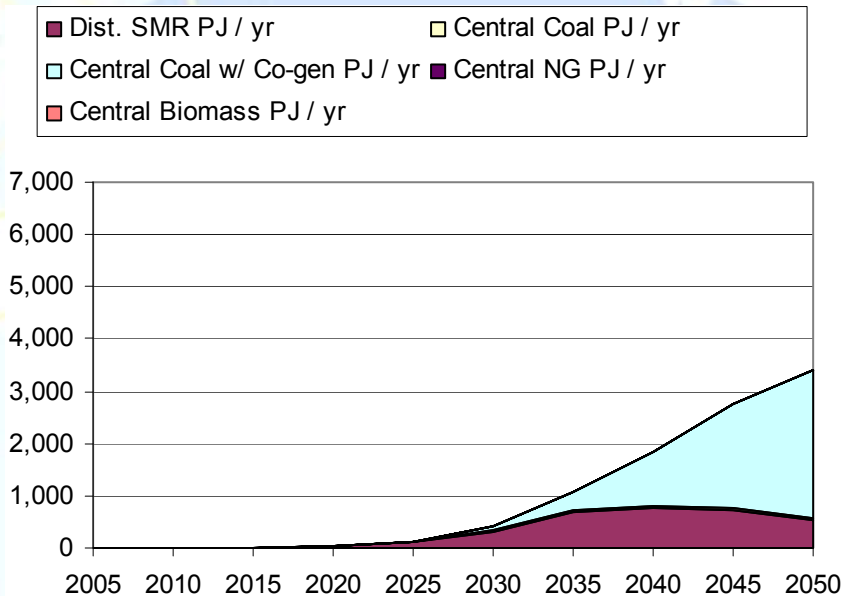
Hydrogen Production Mixture Assuming Technology Success



Vehicle penetration set exogenously

Mix constrained by workshop results

US Markal



Endogenous least-cost calculation
using single- region model with
nested logit function

www.HyWays-IPHE.org

⇒ Endogenous vehicle penetration identifies the impact of assumptions and conditions, but the results may diverge from the views of the stakeholders.

Key Differences in Socio-Economic Modeling

KEY DIFFERENCES:

EU

US

ECONOMIC CALCULATIONS

Macro-economic view: simple approach; lower interest rates

Investor's view: detailed financial and cost calculations; taxes, high rates of return

ENERGY PRICE PROJECTIONS

Higher natural gas, biomass and coal prices

Lower natural gas, biomass and coal prices

KEY ENERGY SCENARIO INPUTS

H₂ vehicle penetration; bounds of H₂ production mix

Resource-cost-curves; technology costs

KEY ENERGY SCENARIO RESULTS

Scenario costs, required infrastructure

H₂ vehicle penetration; least-cost production mix

STAKEHOLDER INVOLVEMENT

Horizontal approach: project and panel level decision making, roadmap tailored to European regions

Vertical approach: Top-down decision making, roadmap (hydrogen energy pathways) by least cost.

LEARNING PROCESS

Learning by doing (global stock)

Three learning mechanisms (domestic stock): searching, manufacturing, doing

INTERLINKAGE OF MODEL TOOLBOX

Socio-economic scope, manual iteration between models+review

Economy and LCA, automated transfers

Vehicle costs and performance

VEHICLE DATA (FC-HYBRID)	EU	US
VEHICLE SIZE	VW Golf size	Mid Size Passenger Car
DISTANCE DRIVEN/YEAR	12,000 km/a	20,000 km/a
TOP SPEED	114 mph (184 km/h)	123.8 mph (198 km/h)
FUEL CELL POWER	80 kW	82.5 kW
WEIGHT	1370 kg	1380 kg
HYDROGEN CONSUMPTION		
NEAR-TERM (~2007)	90.9 mpgge ¹ (0.70 kg H ₂ /100 km)	57.1 mpgge (1.11 kg H ₂ /100 km)
MID-TERM (~2015)	90.9 mpgge (0.70 kg H ₂ /100 km)	65.8 mpgge (0.96 kg H ₂ /100 km)
LONG-TERM (~2030)	90.9 mpgge (0.70 kg H ₂ /100 km)	71.9 mpgge (0.88 kg H ₂ /100 km)
VEHICLE COSTS		
MID-TERM (~2015)	35-37,000 €	28-39,000\$
LONG-TERM (~2030)	22-23,000 €	24-32,000\$

Vehicle stocks vary significantly between different regions and, therefore, the "standard" vehicle for region-specific assessments must be chosen carefully. However, there are also methodological differences in cost estimation and projection (learning mechanism) for vehicles in the EU and the US.

Since evolution and learning of new technology will most likely happen on a global level, this methodology should be harmonized in future work.

"Standard" vehicle types vary in size and performance between the US and EU.

Nevertheless, the resulting vehicle cost data are within the same order of magnitude for the compared scenarios.

Europe: ADVISOR

Advanced Vehicle Simulator
Vehicle performances derive from
CONCAWE, JRC, EUCAR,
Well-to-wheels analysis, March 2007.

US: PSAT

Powertrain Simulation Analysis Toolkit
Argonne's PSAT simulation sized
components, estimated performance
and fuel consumption.

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Roadmapping Questionnaire

- Sent to representatives of the 17 IPHE countries
- 15 responded
- Questions regarding these areas and a summary of the responses:
 - The nation's roadmap
 - Status, philosophy, timeframe
 - Almost all have or are developing government-funded roadmaps but the objectives vary between nations.
 - GHG reduction and energy security are the two main drivers.
 - Tools used to develop the roadmap
 - Models, energy price assumptions, other assumptions
 - Most Asian nations did not use models but most European and American did.
 - Roadmap's projected results
 - Technology costs, economic impact, environmental impact
 - Production technology mix is nation and timeframe specific
 - Most nations investigated hydrogen for both transportation and stationary uses.

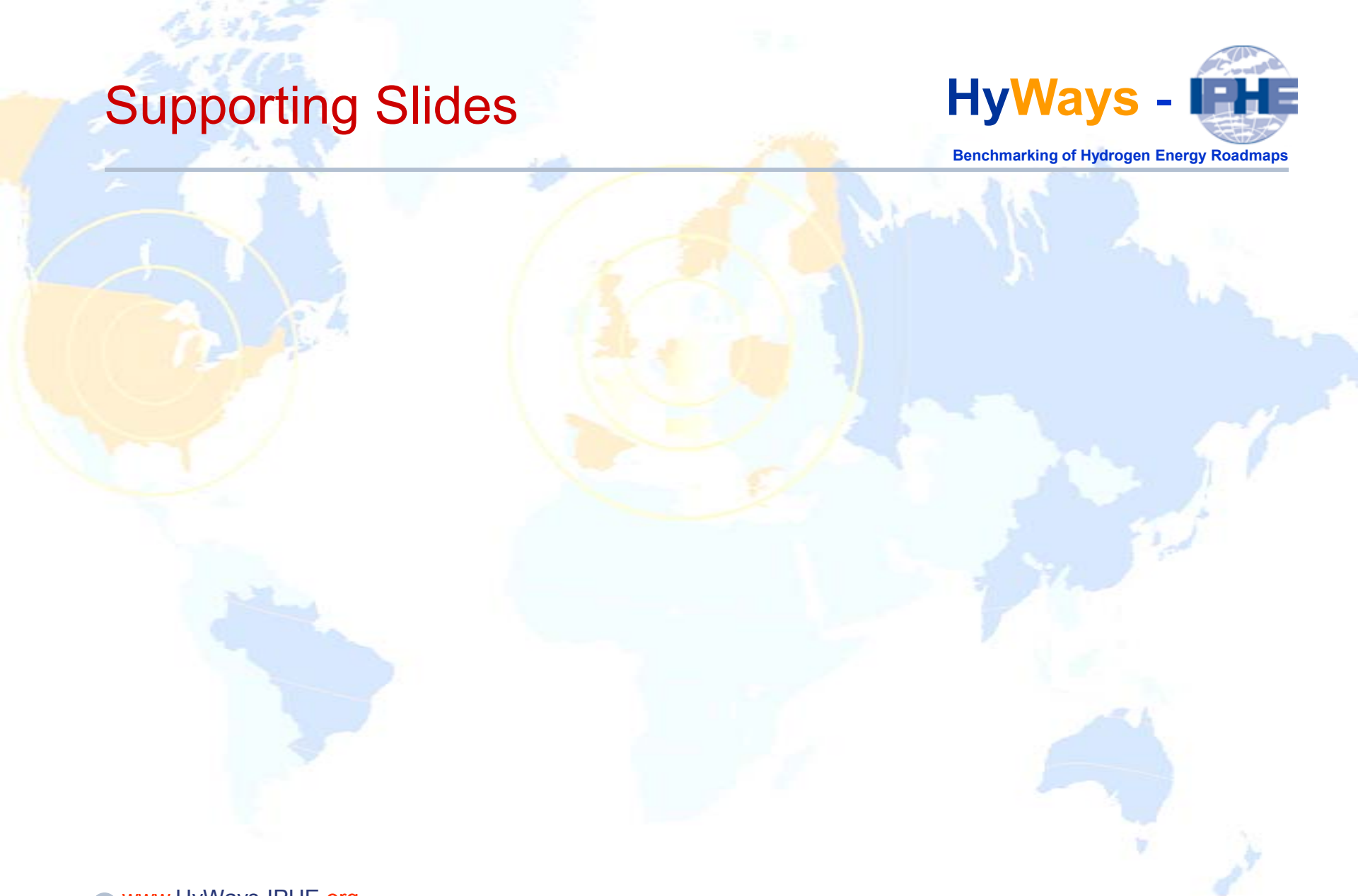
Roadmapping Workshops

- Held in conjunction with the World Hydrogen Energy Conference (Brisbane) and the HyForum (Chang Sha)
- HyWays-IPHE results were presented
- Australia, New Zealand, and Chinese roadmapping activities were also presented
- Facilitated discussions about roadmapping were held
- Conclusions
 - Nations have their own drivers so a “one size fits all” roadmapping expectation is inappropriate
 - Roadmaps are insufficient to gain industry investment. They help understand the drivers but cannot be considered convincing.

Overall Conclusion

Among roadmapping methods, ***"ONE SIZE DOES NOT FIT ALL"*** but a good foundation of resources has been established for future efforts. The roadmap programmes differed, but in both cases successful progress involved two crucial factors: **A STRONG COLLABORATION** between key industries and government with extensive stakeholder input ensuring that technical and market expertise is brought together with policy goals and programmes; **FORMAL SYSTEMS ANALYSIS** describing the energy use, infrastructure, cost and emissions of hydrogen technology and underpinning the feasibility for the roadmap implementation.

Supporting Slides



The screenshot shows a web browser window displaying the HyWays-IPHE website. The browser's address bar shows the URL www.hyways-iphe.org. The website's header features the HyWays-IPHE logo and a navigation menu with links for 'home', 'contact', and 'partner log-in'. A sidebar on the left contains the European Union flag and the text 'HyWays - IPHE is funded by the European Commission'. The main content area has a 'Welcome' section followed by a heading 'HyWays-IPHE'. Below this, there are three paragraphs of text describing the project's goals and activities. The browser's taskbar at the bottom shows the 'Internet' icon.

HyWays - IPHE
Benchmarking of Hydrogen Roadmap Models and Tools

home contact partner log-in

Welcome

HyWays-IPHE

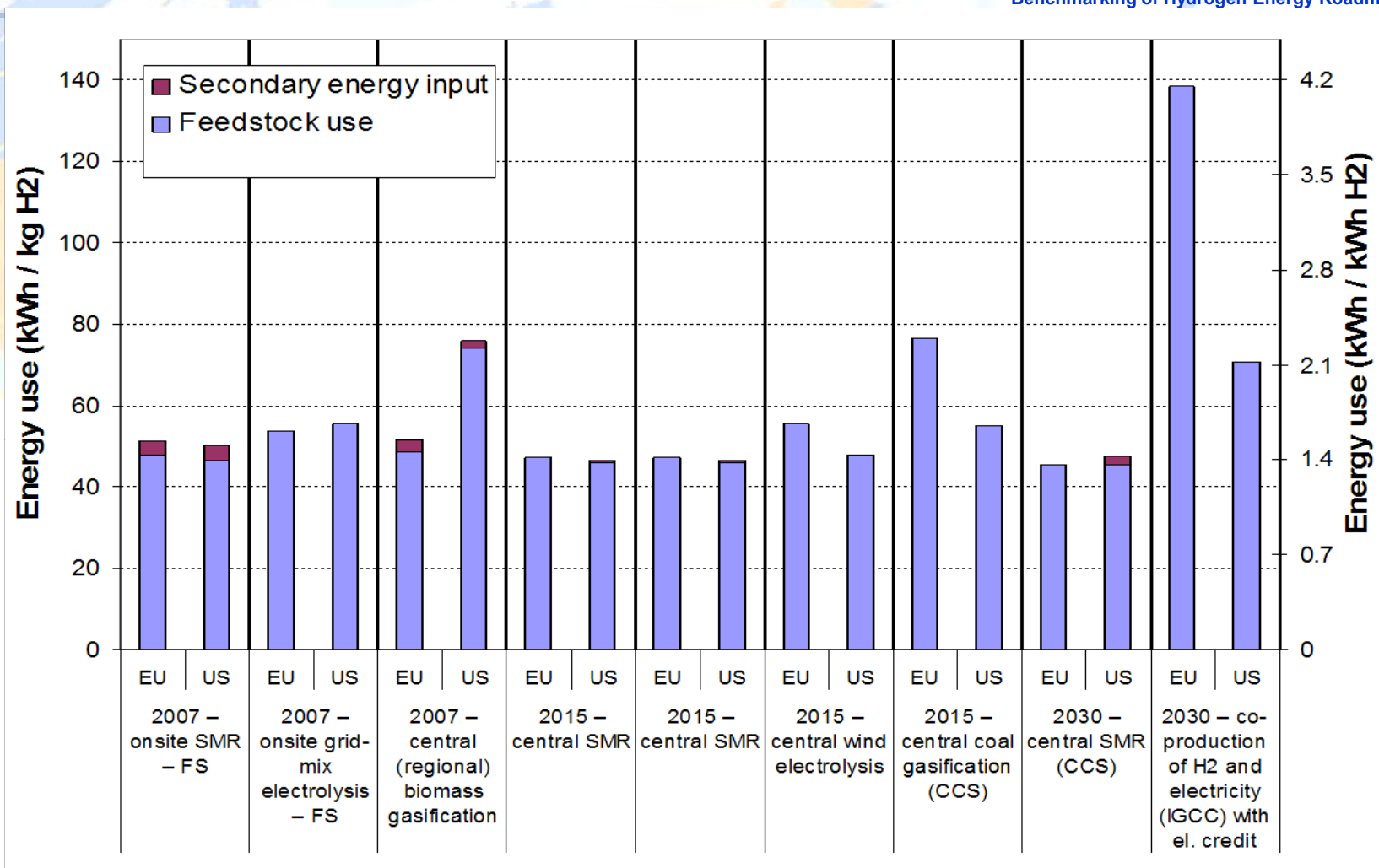
HyWays IPHE is a specific support action (SSA) to assess and compare the development efforts for the European Hydrogen Energy Roadmap prepared by HyWays with international roadmapping or comparative activities of IPHE partner countries.

In a first step, it aims at an in-depth assessment and comparison of the individual elements of the national/ regional strategies, modelling approaches and experiences in the EU and the U.S.. This will include infrastructure analysis, stakeholder consultation processes, actor analysis, micro-, meso- and macro-economic modelling, Well-to-Wheels (WtW)- analyses, cashflow analysis, interfaces and interaction between the different types of models used, basis for scenario development, etc.

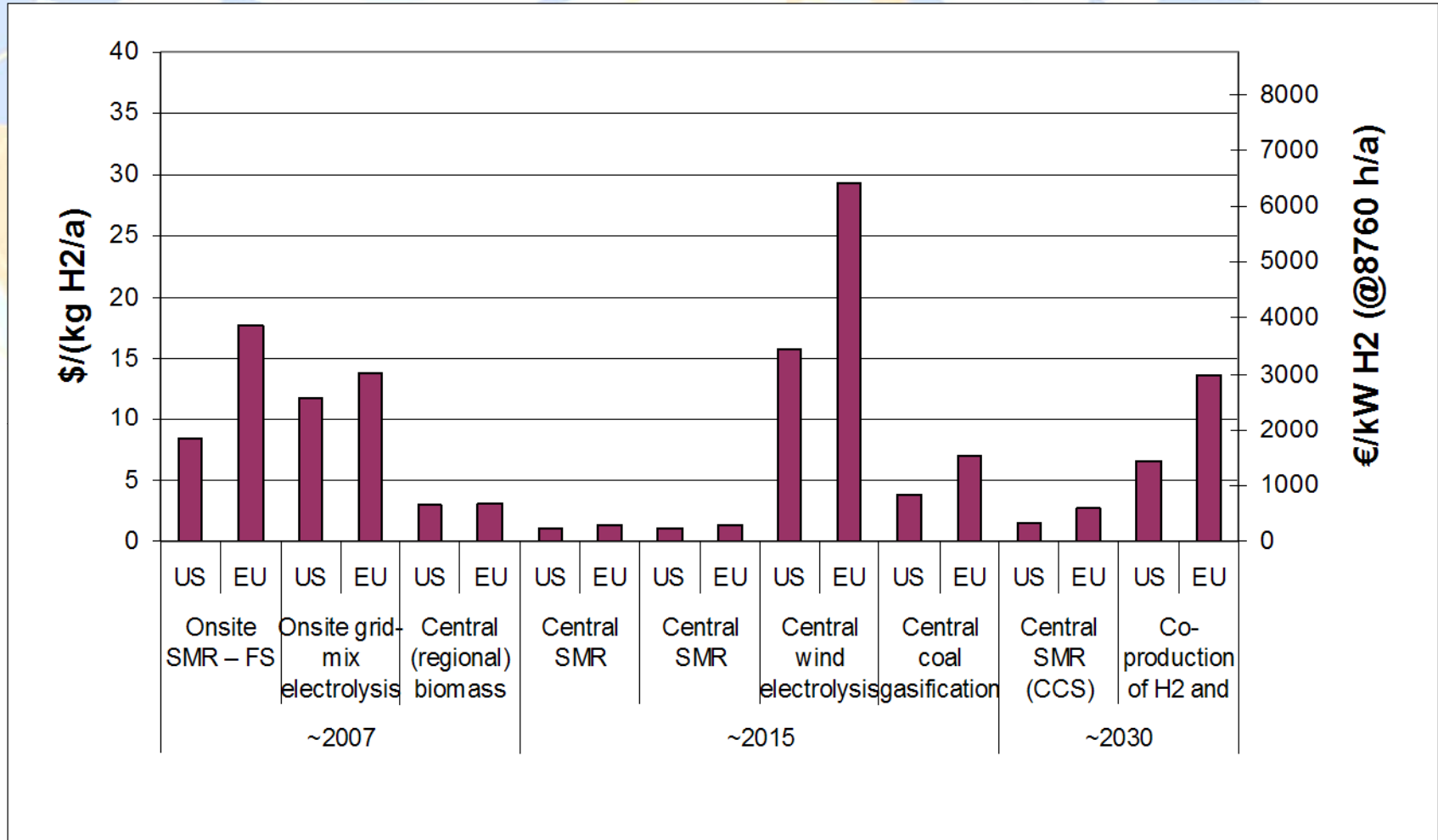
Modellers from the different nations/world regions shall compare in detail their models and experiences in dedicated workshops in order to foster a better mutual understanding of the models and their contribution to the hydrogen road mapping process, facilitate the exchange of the methodologies and, where applicable, endorse the adoption of individual approaches from each other. This may include tasks and goals of expected results, models used, stakeholders involved, process related issues, communication with stakeholders and dissemination activities, timelines, and progress. Whenever applicable a benchmarking between individual models (e.g. for the EU-US case: E3database and H2A+GREET) may be performed using generic datasets.

In a second step, the project aims at broadening its scope within IPHE by including and involving other IPHE partner countries such as Japan, China, India etc. Workshops will be held, introducing these partners into the EU-U.S. work and getting them engaged in this process.

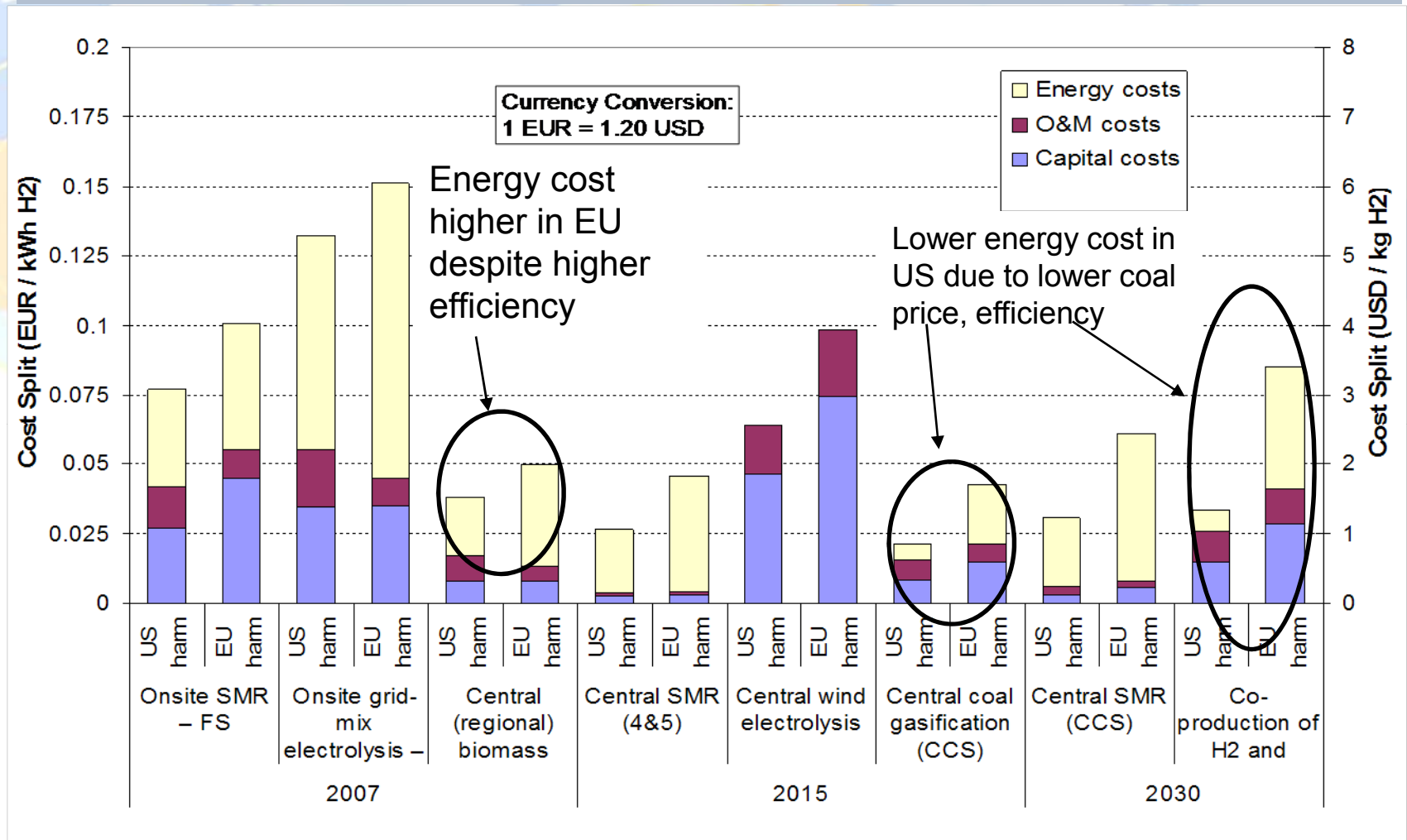
Production Comparison – Energy use



Production Comparison – Specific Capital Costs



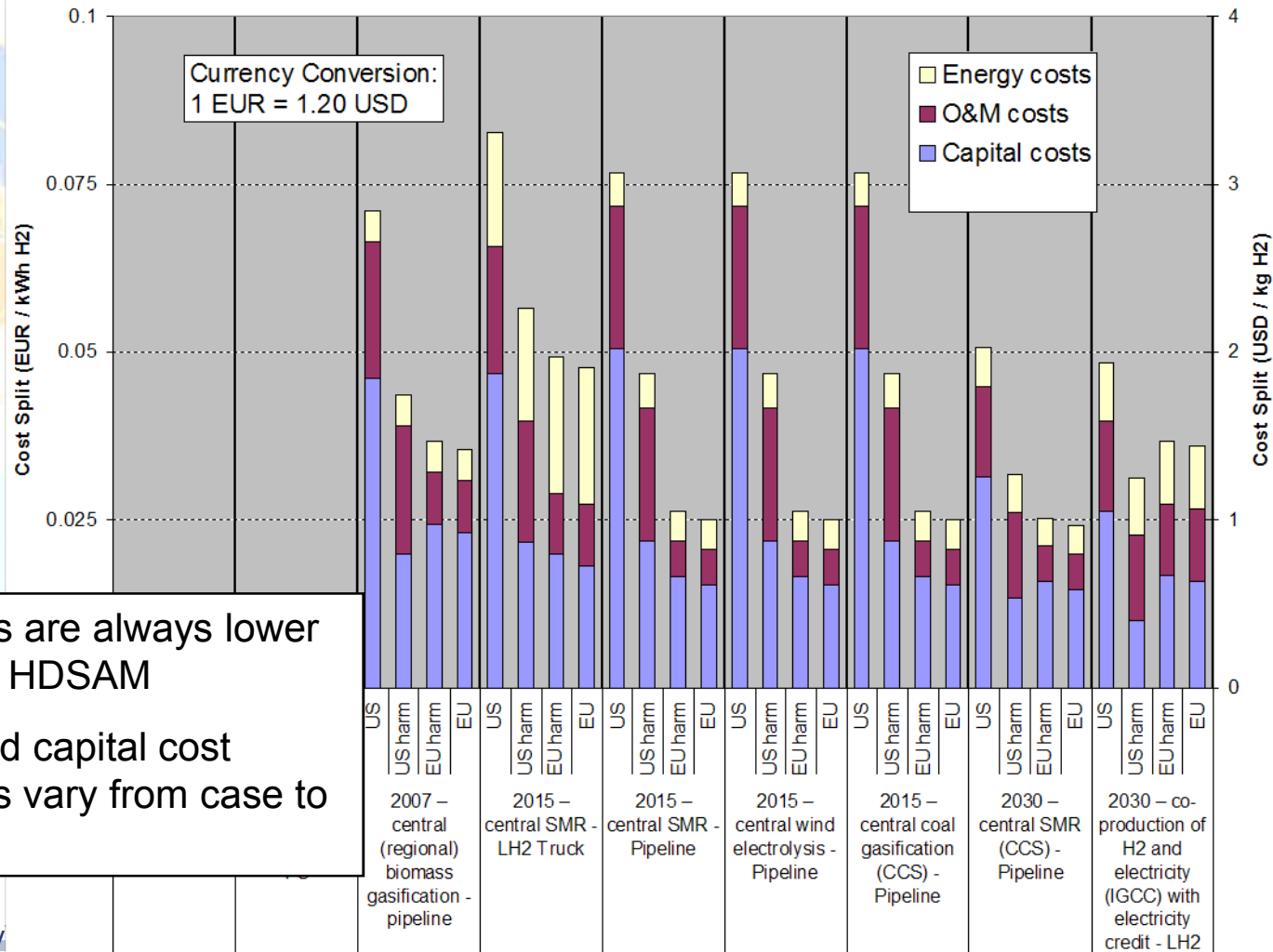
Production comparison – financially harmonized chains



Delivery Scenarios We Compared

Pathway		Population	# of Hydrogen Vehicles	Daily Demand (kg/day)	# of Fueling Stations
3: ~2007 Pipeline	HDSAM	93,800	34,800	19,335	19
	E3		84,300		15
4: ~2015 LH ₂ Trucks	HDSAM	356,300	135,700	65,430	63
	E3		285,300		52
5-7: ~2015 Pipeline	HDSAM	105,300	40,100	19,335	19
	E3		84,300		15
8: ~2030 Pipeline	HDSAM	115,000	43,800	19,335	19
	E3		84,300		15
9: ~2030 LH ₂ Trucks	HDSAM	1,199,000	445,000	196,291	188
	E3		855,900		156

Levelized Cost of Delivery Comparison

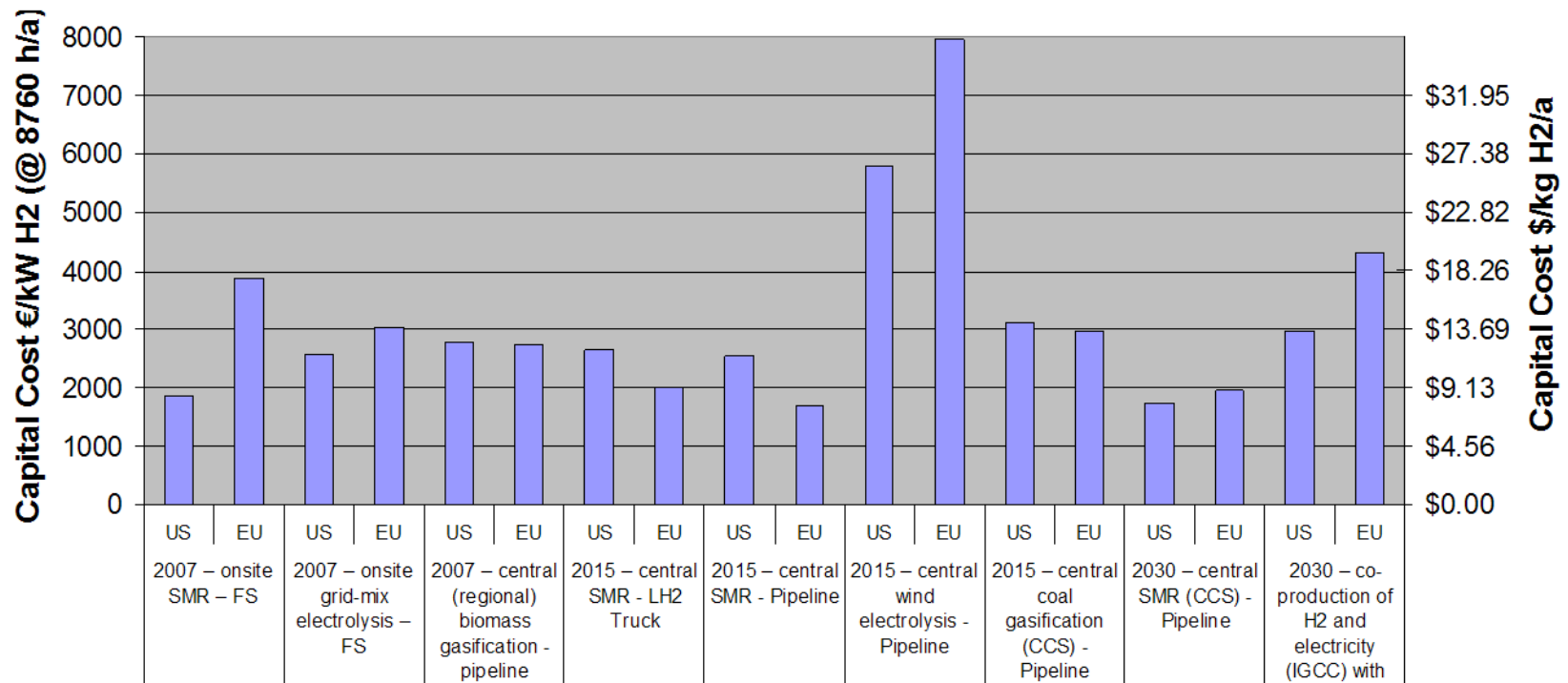


O&M costs are always lower in E3 than HDSAM

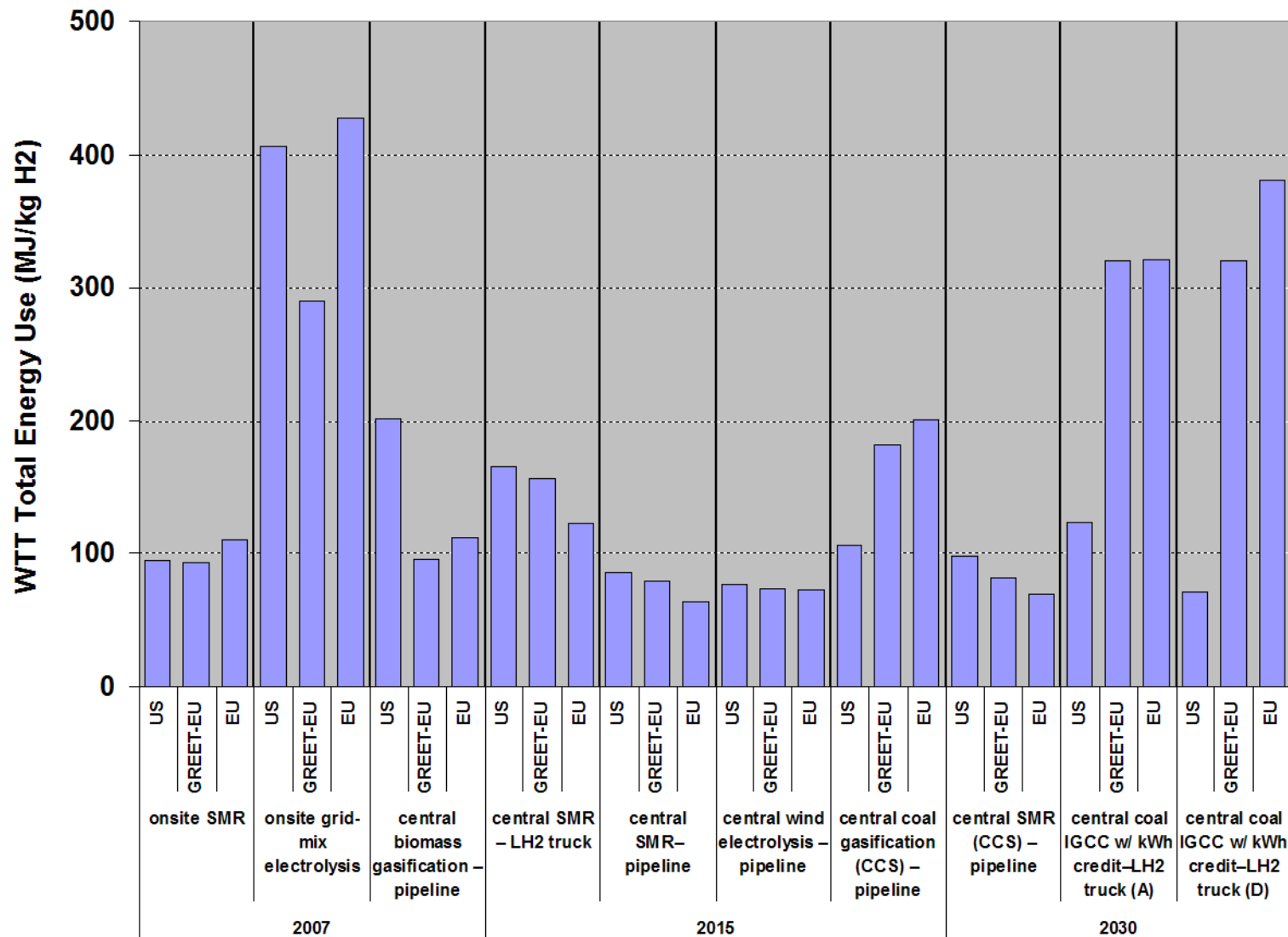
Energy and capital cost differences vary from case to case

Pathway Capital Investment Comparison

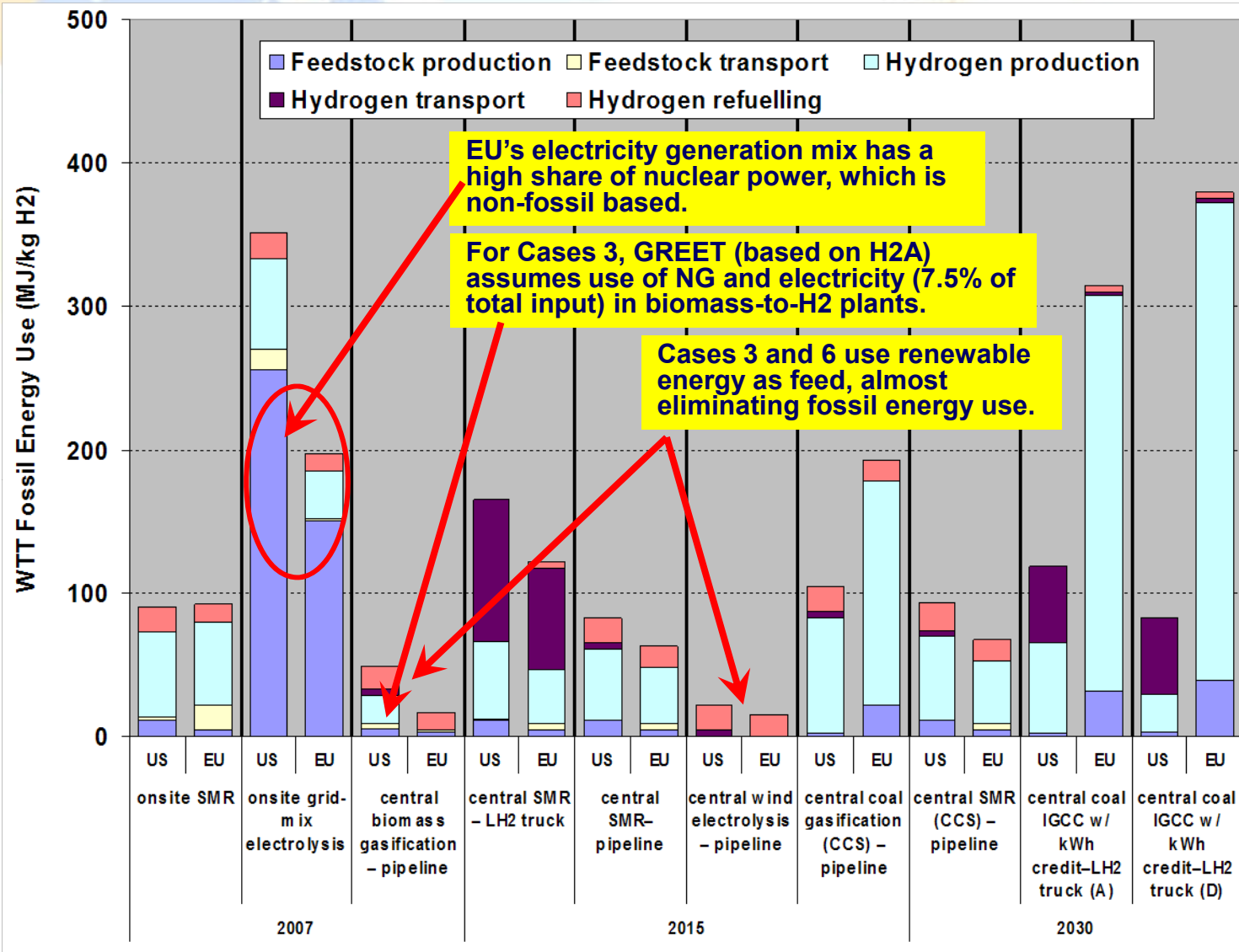
Full Pathway - Capital Investment



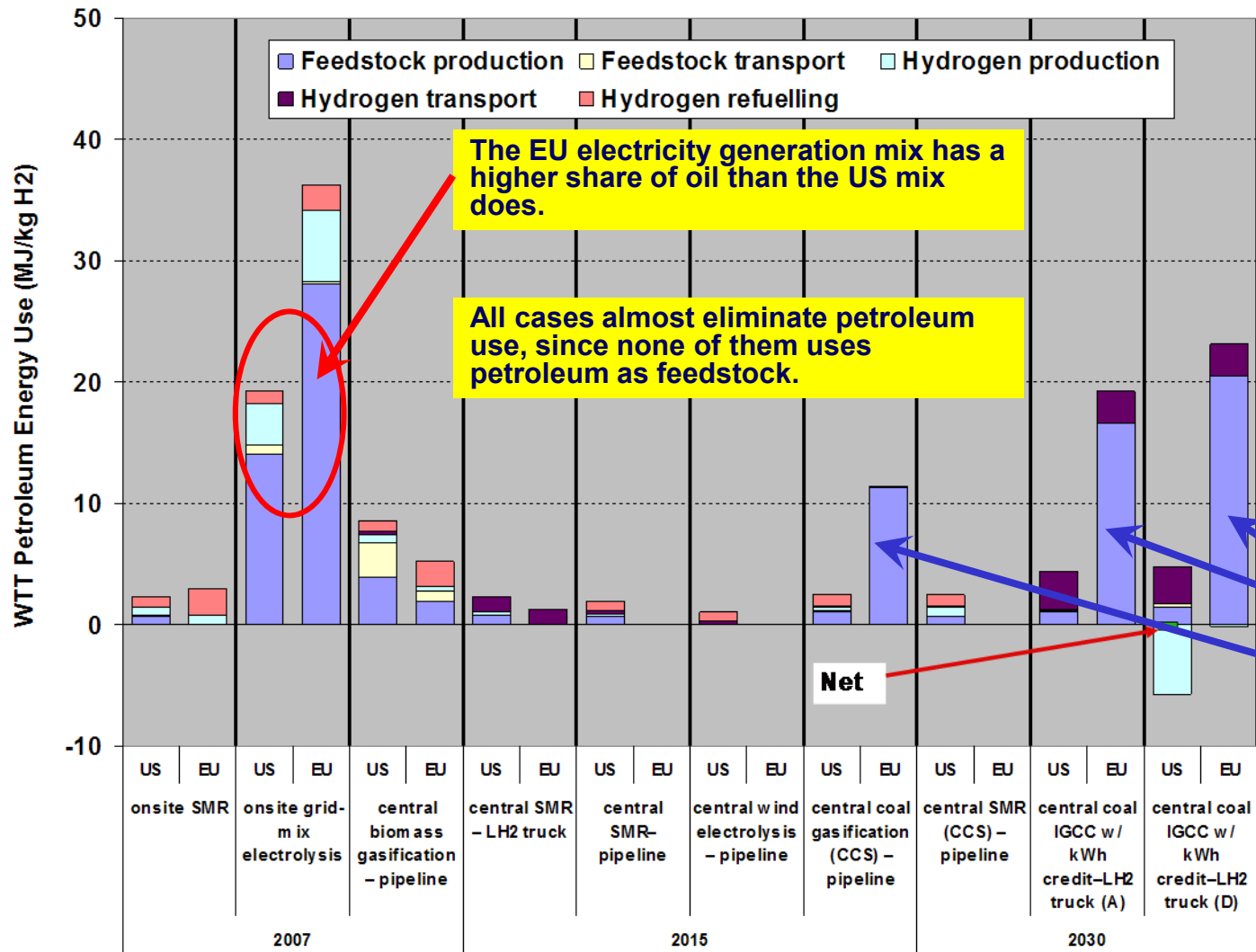
WTT Comparison: Total Energy Use



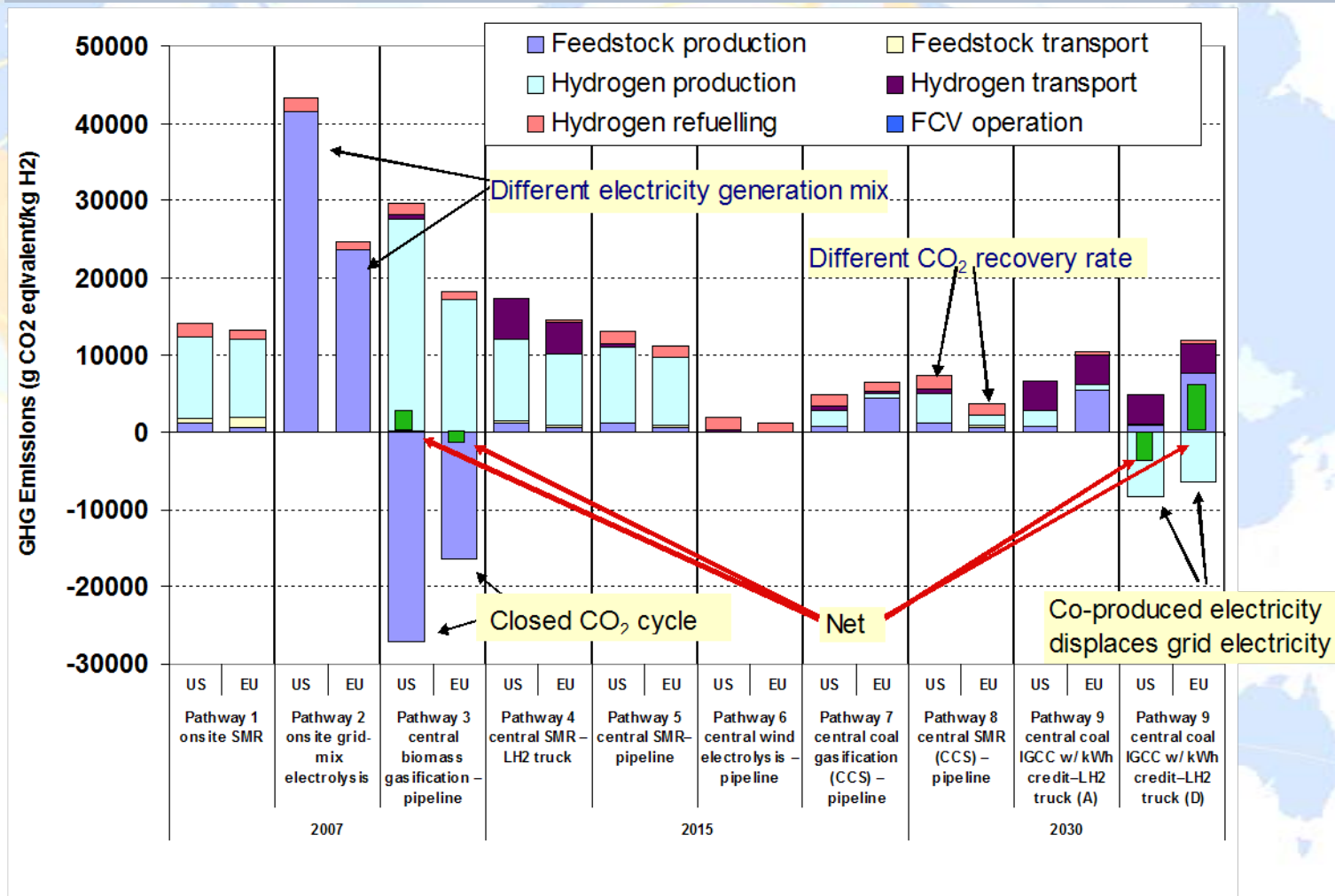
WTT Comparison: Fossil Energy Use



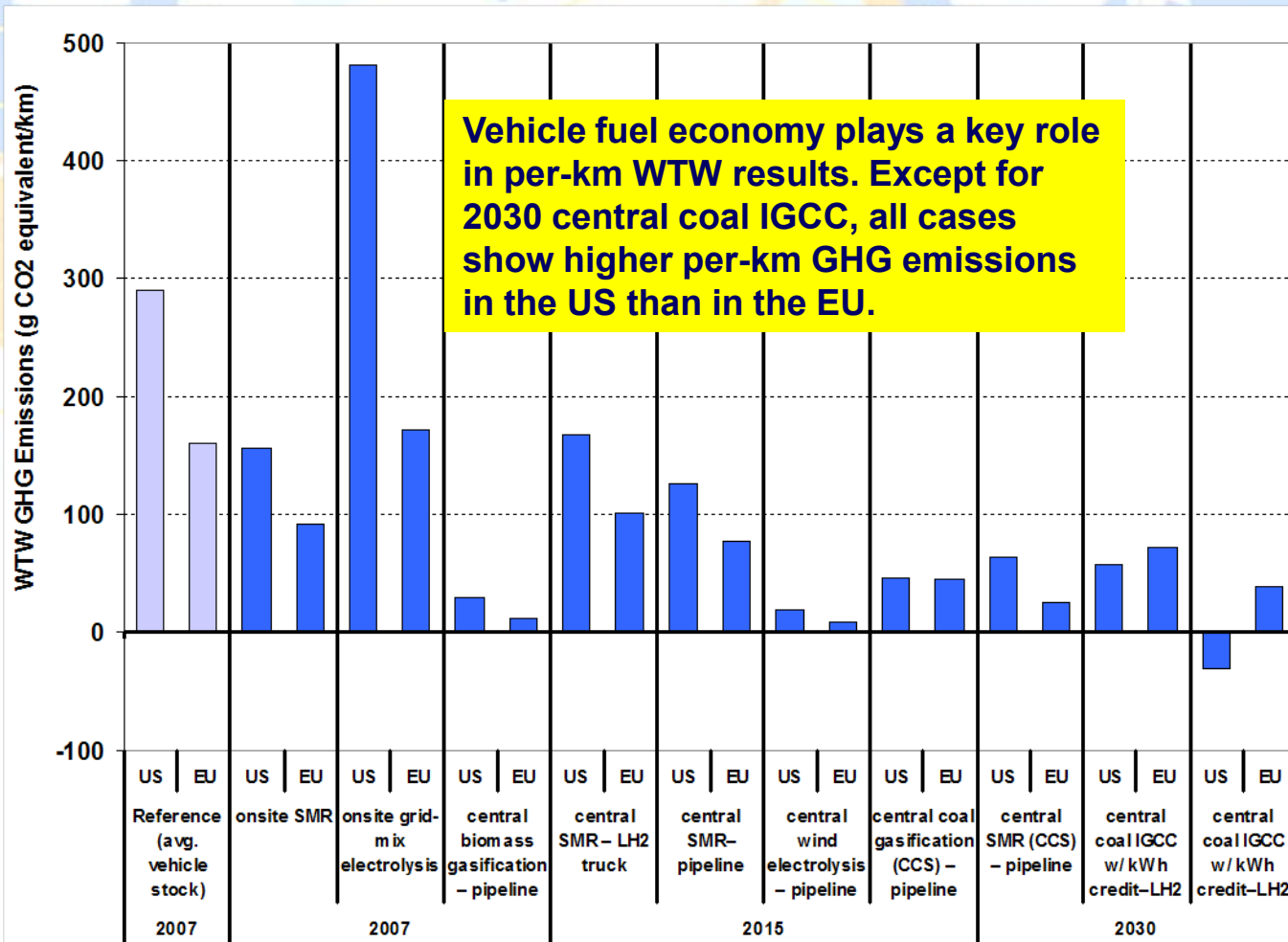
WTT Comparison: Petroleum Use



WTT Comparison: GHG emissions



WTW Comparison: GHG Emissions (km driven)



Effects and ranges of results may affect decisions

- May help define optimistic and pessimistic scenarios
- Ranges may overlap indicating that one result is not as much better than another as single deterministic values indicate.
- Some stochastic analyses have been completed in both the US and Europe; however results have not yet been included into the roadmaps

Challenges of Hydrogen Modeling

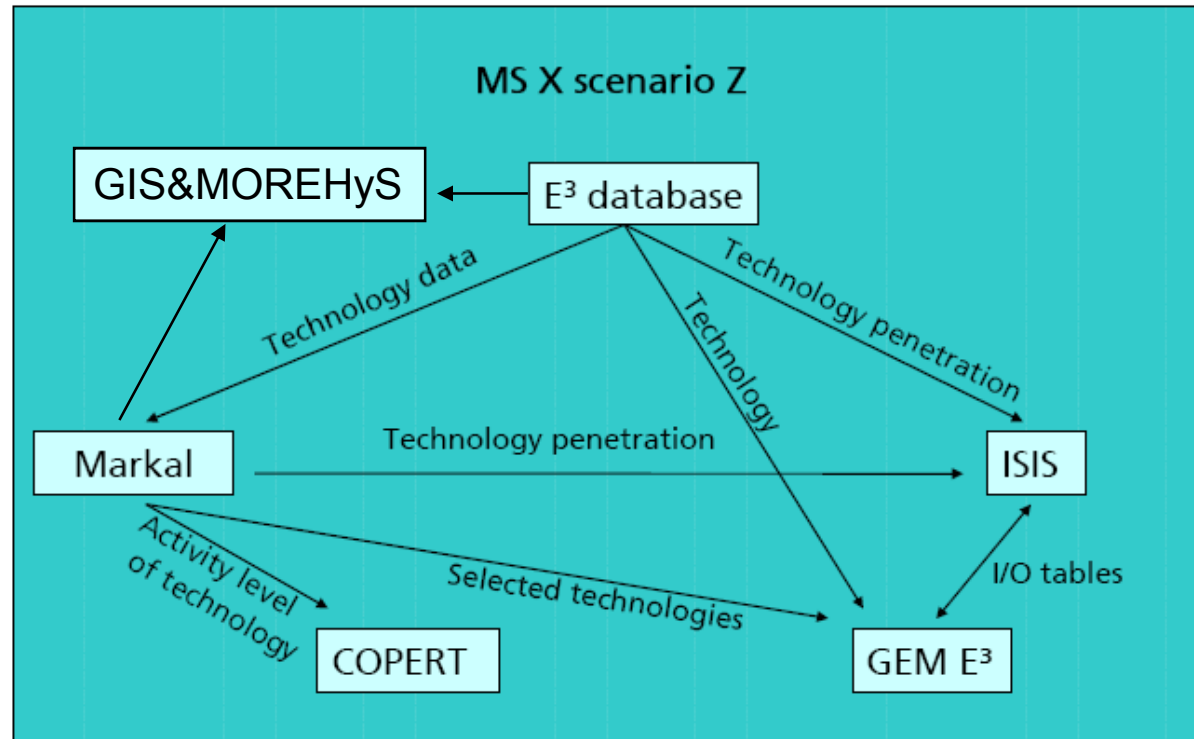
- Representation of **technological change** and its components for vehicles and fuels
 - cost reductions through technological progress, scale economies, and Learning-by-Doing.
- Accounting for H₂'s specialities **for geographic/spatial modeling issues**
 - spatially-related costs and markets
 - the evolution of geographically differentiated infrastructure.
- Describing plausible **evolution through time of demand & infrastructure**
 - Smooth succession of compatible Technologies or sudden (“disruptive”) change?
- Specifying the **nature and structure of consumer choice** among new vehicle types
- Capturing the state of knowledge regarding how consumers value **fuel availability and diversity of vehicle make and model** choice;
- Representation of **interactions with other energy markets**, especially feedstock supply costs, & competition with other fuels/vehicles.
- Interactions of a national program with **global vehicle markets** during the transitions stage
- Accounting for impacts of **risk and expectations**.

Main Types of Models & Tools Identified: Key question & models in use

MAJOR TYPES OF MODELS USED FOR ROADMAP DEVELOPMENT	KEY QUESTION ADDRESSED BY THE MODELS	GREET	E3DATABASE	PSAT	H2A-PRODUCTION	H2A-DELIVERY	MSM	MOREHYS	HDSAM	HyDIVE	HyPRO	HyTRANS	MARKAL	NEMS-H2	ETP
LCA LIFE CYCLE ANALYSIS	Energy efficiency, greenhouse gas and pollutant emissions of hydrogen energy chains, cradle-to-grave	US	EU												
TEC TECHNOLOGY AND ENGINEERING COSTS	Technical description and cost projection of vehicle and fuel production and delivery technologies		EU	EU	US	US	US								
HID REGIONAL HYDROGEN INFRASTRUCTURE DEVELOPMENT	Infrastructure scenario planning: Spatial pattern, mix & cost of infrastructure to meet estimated H ₂ demand in given city or region							EU	US	US	US				
MT MARKET DEVELOPMENT AND TRANSITION	Evolution over time of fuel infrastructure and vehicles in market, impact of policies on transition											US			
ESM ENERGY SYSTEM MODELLING	System-wide balances of energy and fuel use, and GHGs, across sectors and nationally or internationally												EU	US	EU

Comparison of model interactions

Models used and linkages in HyWAYS



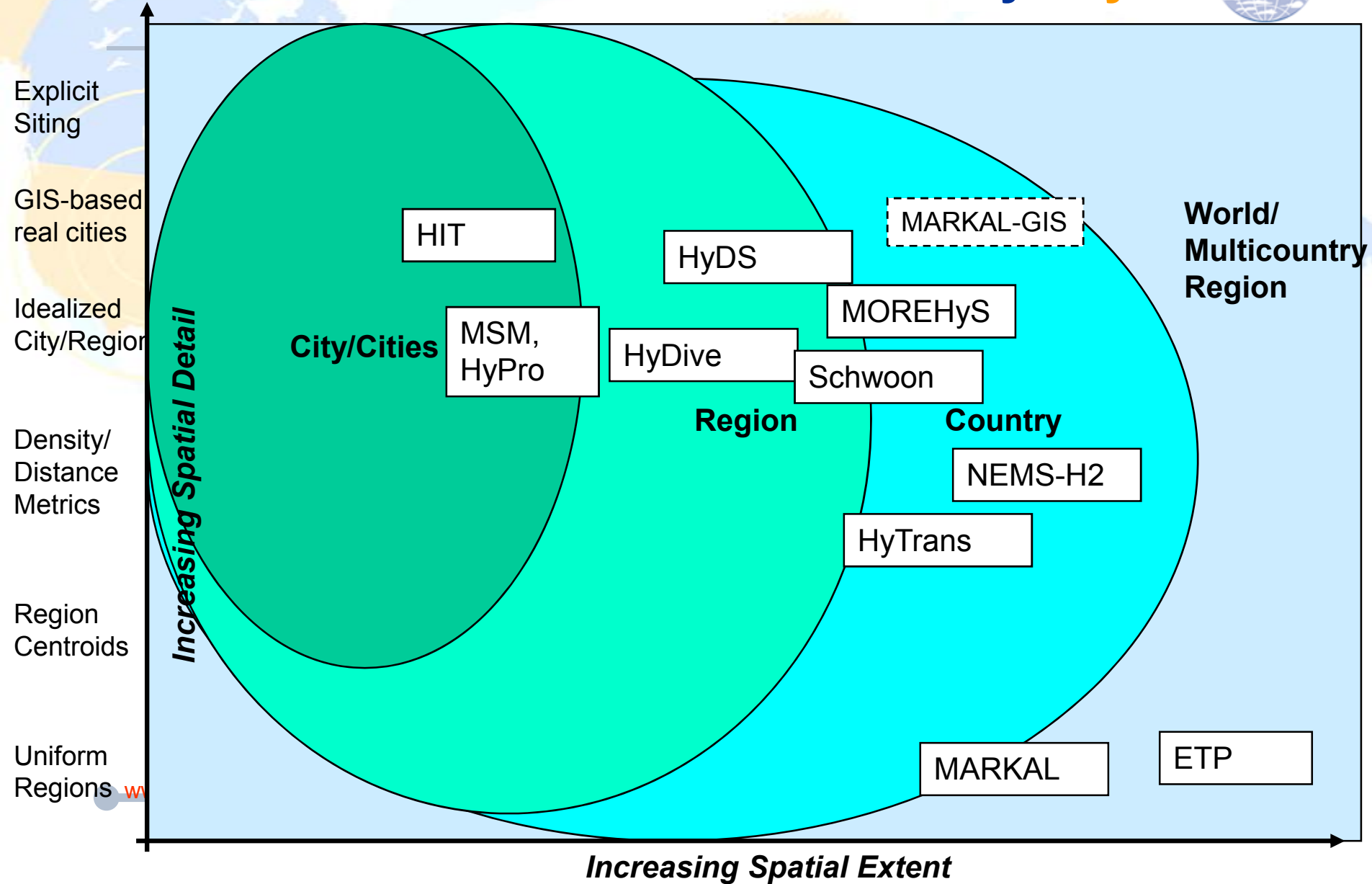
Source: Seydel & Weitschel 2004. "HyWays - Definition of Model Data Exchange and Model Interfaces - D3.2_REPORT_FINAL"

HyWays - IPHE
Benchmarking of Hydrogen Energy Roadmaps

Benchmarking of Hydrogen Energy Roadmaps



Spatial focus (extent and detail)



HyWays - IPHE
Benchmarking of Hydrogen Energy Roadmaps



Comparison of Techno-Economic Data Sources

EU

HyWays-Penetration rates, main assumptions

Markal-Model (energy system optimisation)

Regional demand & filling station development (GIS based approach)

Current development

Regional production & transport (MOREHyS, production-filling station optimisation approach)

Current development

US

NEMS (non-H2 variety)

Early-Transition Exog. FCV sales to 2025

H2A

← interpolation →

H2A

→ extrapolation →

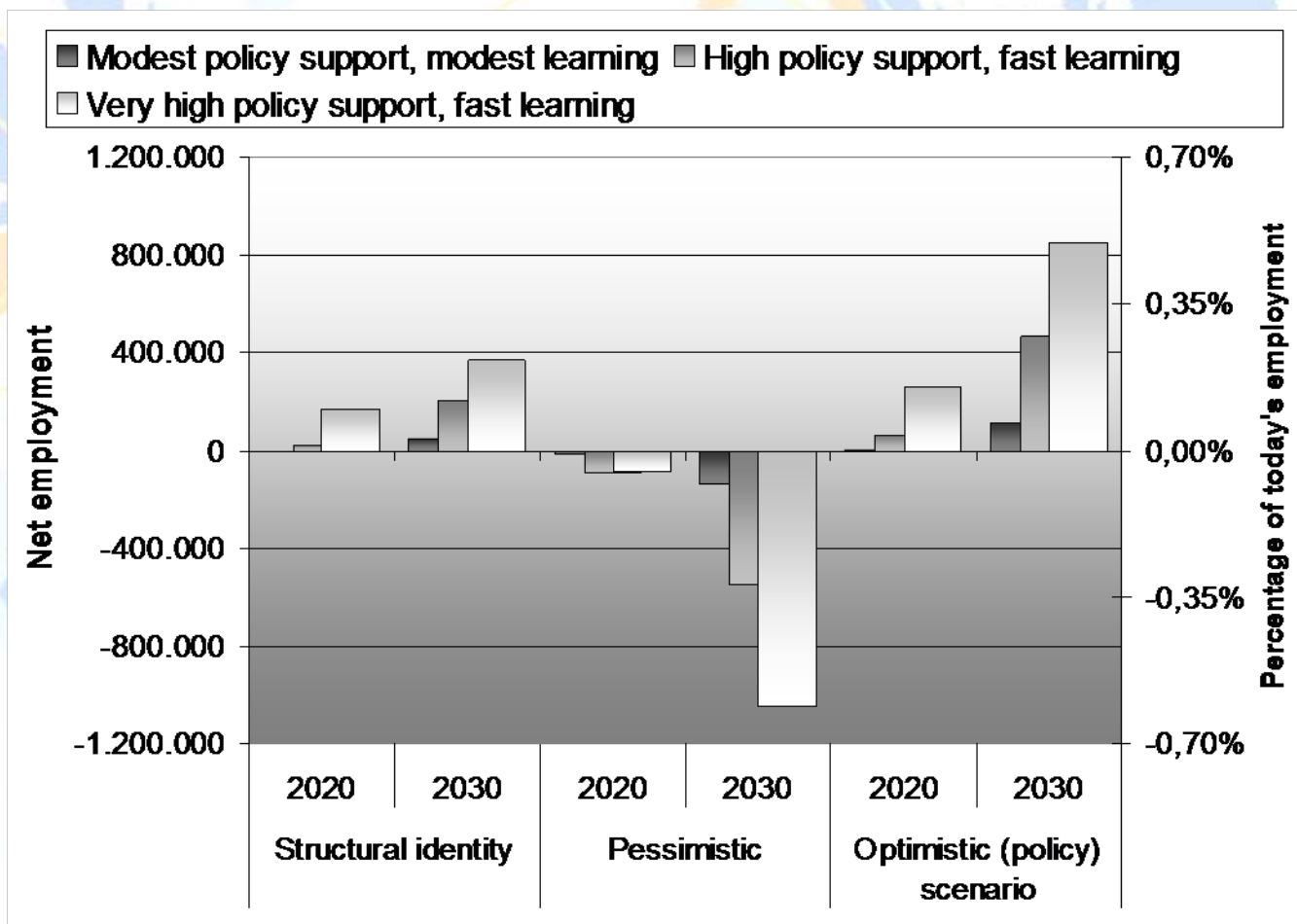
HyPro, HDSAM regional infrastructure studies

HyTrans, Long-run Nationwide market studie

Comparison of Methodology of Model Interactions

- **HyWays**
 - Data exchange done by the users with standard data forms
 - Feedback with stakeholders was involved
 - Sensitivities are run
- **Macro-System Model**
 - Currently provides full pathway analysis capability (comparable to the E3db)
 - Automated data exchange using a common interface
 - Web-based graphical user interface
 - Iterative calculations not yet needed

HyWays Employment Study Results



Models involved in vehicle comparison

United States PSAT

Powertrain Simulation Analysis Toolkit

Developed by Argonne National Lab

The Argonne PSAT modelers ran simulation analyses for all the advanced technologies to size components and estimate performance and fuel consumption.

Europe ADVISOR

Advanced Vehicle Simulator

Developed by National Renewable Energy Lab

No direct modeling has been made in the HyWays project, but vehicle performances derive from CONCAWE, JRC, EUCAR, *Well-to-wheels analysis*, March 2007.

Vehicle Fuel Economies used for Scenario Definition

- Vehicular fuel economy
 - US value is dependent upon timeframe
 - Assumes technology improvements for the vehicle
 - 2007 – 57 miles / kg vs. = 0.36 kWh / km
 - 2015 – 66 miles / kg vs. = 0.31 kWh / km
 - 2030 – 72 miles / kg vs. = 0.29 kWh / km
 - EU uses 89 miles / kg = 0.24 kW h / km
 - Due to differences in vehicle size, driving cycles, and estimation method

Vehicle Cost & Performance Projection Comparison

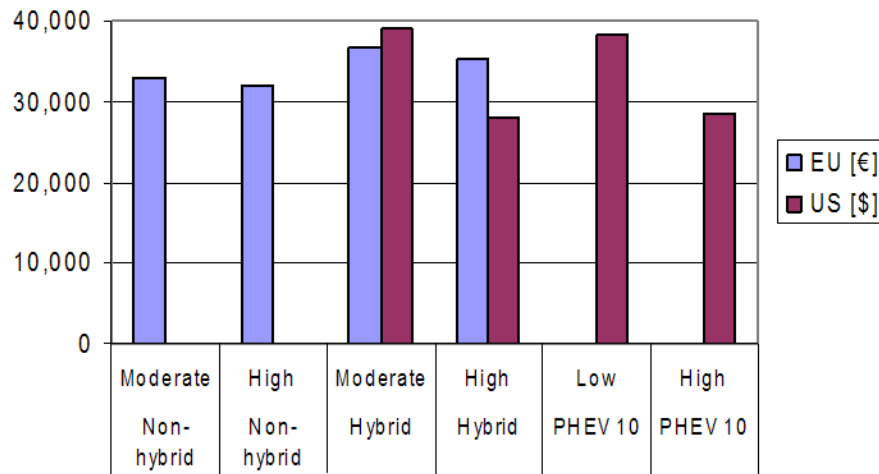
EU-Timelines		2015		2025	
Learning rate (High Policy Support)		Medium	High	Medium	High
Volume scenarios EU+US	Mio units	0,03	0,06	9	18
Comp. Hydrogen @ 70 Mpa	€/kWh	21	18	6	5
Electric motor + controller	€/kW	71	64	34	27
Battery					
Li-ion Battery	€/kWh	683	618	327	262
FC system	€/kWnet	112	112	31	24

Costs are built up from drivetrain components, based on posited vehicle design and market introduction rates. Component-by-component comparison of assumptions necessary, but challenging.

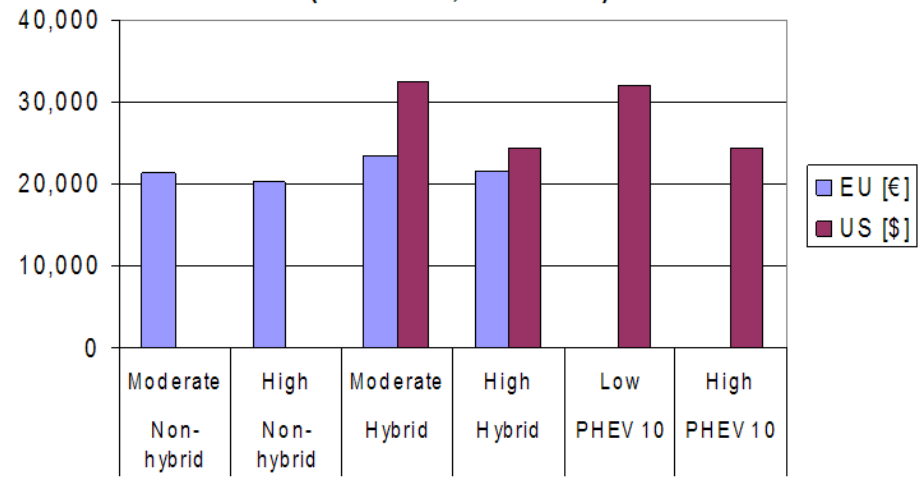
US-Timelines		2015			2030	
		Low	High	FC Goal	Low	High
Comp. Hydrogen	\$/kWh	15	4	2	15	2
Electric Motor&Controller	\$/kW	14	12	12	11	7
Battery						
HEV	\$/kWh	1010	500	500	750	400
PHEV10	\$/kWh	418	367	367	367	220
BEV	\$/kWh	285	250	250	250	150
Fuel Cell	\$/kW	67	45	45	52	30

Vehicle Cost & Performance Projection Comparison

Hydrogen Fuel Cell Vehicle Retail Price - 2015



Hydrogen Fuel Cell Vehicle Retail Price
(EU - 2025, US - 2030)

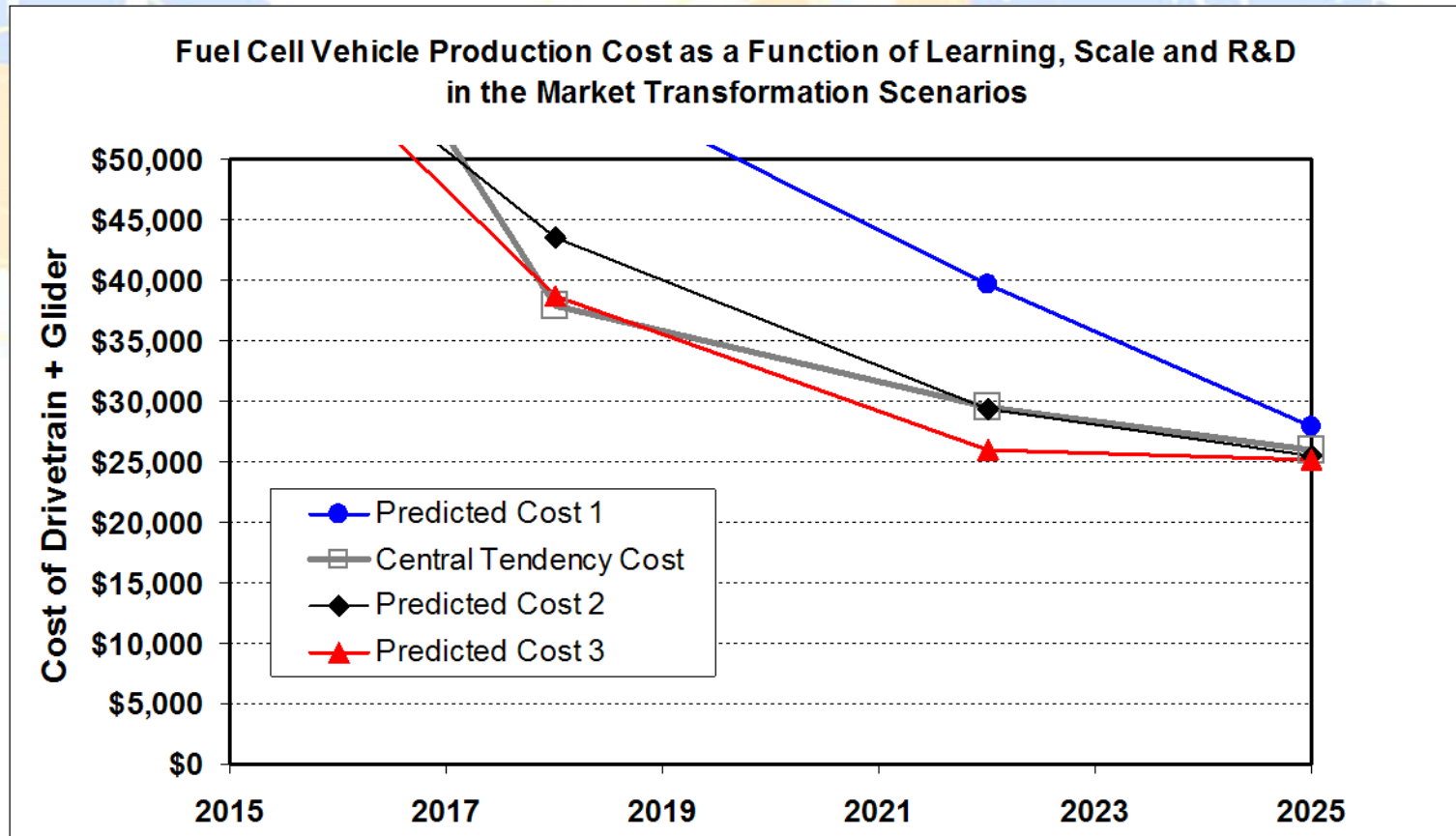


Costs declining for all H2-FCV vehicle types, somewhat faster under these cases for EU.

Vehicle Cost & Performance Projection

Comparison: Cost Reductions Over Time Depend on Rate of Introduction in Scenario

Effect of combined learning dimensions and sequencing for 3 U.S. deployment scenarios



Vehicle Cost & Performance Projection Comparison

- Different models used:
 - Europe: ADVISOR (derived from CONCAWE-EUCAR-JRC study)
 - US: PSAT (sizing components, estimated performance, and fuel consumption)
- Different continents require different vehicle assumptions
 - HyWays – VW-Golf class
 - US – Mid-size passenger car
- Different portfolio and configurations of hydrogen fuel cell powered vehicles require to devise a common assessment framework (component level approach)
 - Hybrid hydrogen FC vehicle the only common vehicle assessed in both sides although with a different configurations
 - Non hybrid FC in the EU, while PHEV 10-40 investigated in the US
- Different learning methodologies emphasize the need for a harmonized methodology for accurate comparison:
 - EU: learning by doing starting with an integrated and interactive industrial chain, exponential curve
 - US: 3 separate dimensions, learning by searching, economies of scale, learning by doing, asymptotic curve
- Cost is highly dependent upon market size
 - Learning function dependent upon technology, market size, market history (growth rate)
 - Estimated global market size is likely to be better than national market because learning is made by multi-national OEMs

WP3: Comparison of socio-economic models and stakeholder involvement

Task	Comparison type
Infrastructure/ transition analysis	1. Compare model objectives, methodology, result type. 2. Philosophy behind the roadmapping process Models: MoreHyS/HyWays methodology vs. HyTRANS
Stakeholder involvement	Describe how SI works on each side (US: Tech teams, EU: HyWays) => Recommendations for EU/JTI
Energy system modelling/ energy price	Impact of energy prices on results => use existing oil price sensitivities
Economic impacts	Describe and try to discuss the importance of employment/GDP on each side.
Interlinkage models and tasks	EU: Explain interfaces on models and overlapping, learnings and experiences. US: Incentives to start model developments
Probabilistic analysis	CO2/energy MonteCarlo analysis. H2A/HDSAM cost bandwidth, see where E3 value is in the bandwidth
H2 Vehicle costs and targets	Compare fuel cell, storage, electronics targets and state of the art

Macro-Economic Estimates – Employment Studies

- Both the EU & the US used an input output approach (EU to 2030; US to 2050)
- EU also used a CGE model to analyse GDP effects
- The US model is more detailed in its disaggregation of employment by sector and type
- The EU model is integrated in the harmonized HyWays framework and results are available for each of the 10 HyWays countries
- Both sides disaggregated results, the EU for the 10 HyWays countries, the US for 5 regions of interest
- Both sides looked at international competitiveness

Program Structure & Stakeholder Involvement

Nations and government entities choose different emphases of top-down and bottom-up program designs, some combination of approaches proves helpful

United States

Primarily government facilitated

DOE coordinates a collaborative effort to set technological targets. Industry groups, states & cities, HTAC, NRC, and other stakeholders are involved in the effort. DOE publishes the targets.

DOE supports research

Project input from stakeholders including an annual project review meeting

Obvious connection between program goals and projects

Large national plan that has not been broken into regional plans

Europe

Primarily industrial-stakeholder facilitated

A Joint Technology Agreement (JTI) calls for proposals and selects projects. It involves partners' cost-share (primary funding source), EC funding, and member states funding.

Initiative and supporting role of the European Hydrogen and Fuel Cell Technology Platform (HFP)

JTI will further define connections between goals and projects

Key role of Member-States and Regions with their own plan and selections

Stakeholder Input Groups and Types of Input

	California Fuel Cell Partnership	State Energy Programs	FreedomCAR & Fuel Partnership ESG	FreedomCAR & Fuel Partnership Tech Teams	International Partnership for the H2 Economy/IPHE	National Research Council	Hydrogen and Fuel Cell Technical Advisory Committee/HTAC	Annual Merit Reviewers	Academic Institutions and Personnel	Hydrogen & Fuel Cell Technology Platform for Europe/HFP ¹	HyWays Consortium	HyWays Project Member States	HyWays Project OEMs	HyWays Project Energy Providers (Oil & Power Companies)	HyWays Project Research Institutes	Executive Advisory Board/External Reviewers
Programmatic Goals (Emissions, Petroleum Reduction, etc.)			*			*	*				*					
Socio-Economic Goals (Employment, GDP growth, etc.)						*	*				*				*	
Programmatic Guidance			*	*		*	*			*	*					
Technology Targets/Goals																
• Hydrogen Production			*	*		*	*	*	*	*	*	*		*		
• Fuel Cell			*	*		*	*	*	*	*	*		*			
• Codes and Standard Development		*		*	*			*	*	*						*
Techno-Economic Parameters				*		*			*		*					
Project Reviews				*	*			*	*							* ²
Deployment Strategies	*	*	*	*		*	*		*	*	*					
Outreach/Education	*	*			*	*	*	*	*	*	*					

Notes:

1. Expected to be covered by the JTI in the future.
2. Both the HFP and HyWays projects are reviewed by an executive advisory council and external reviewers.

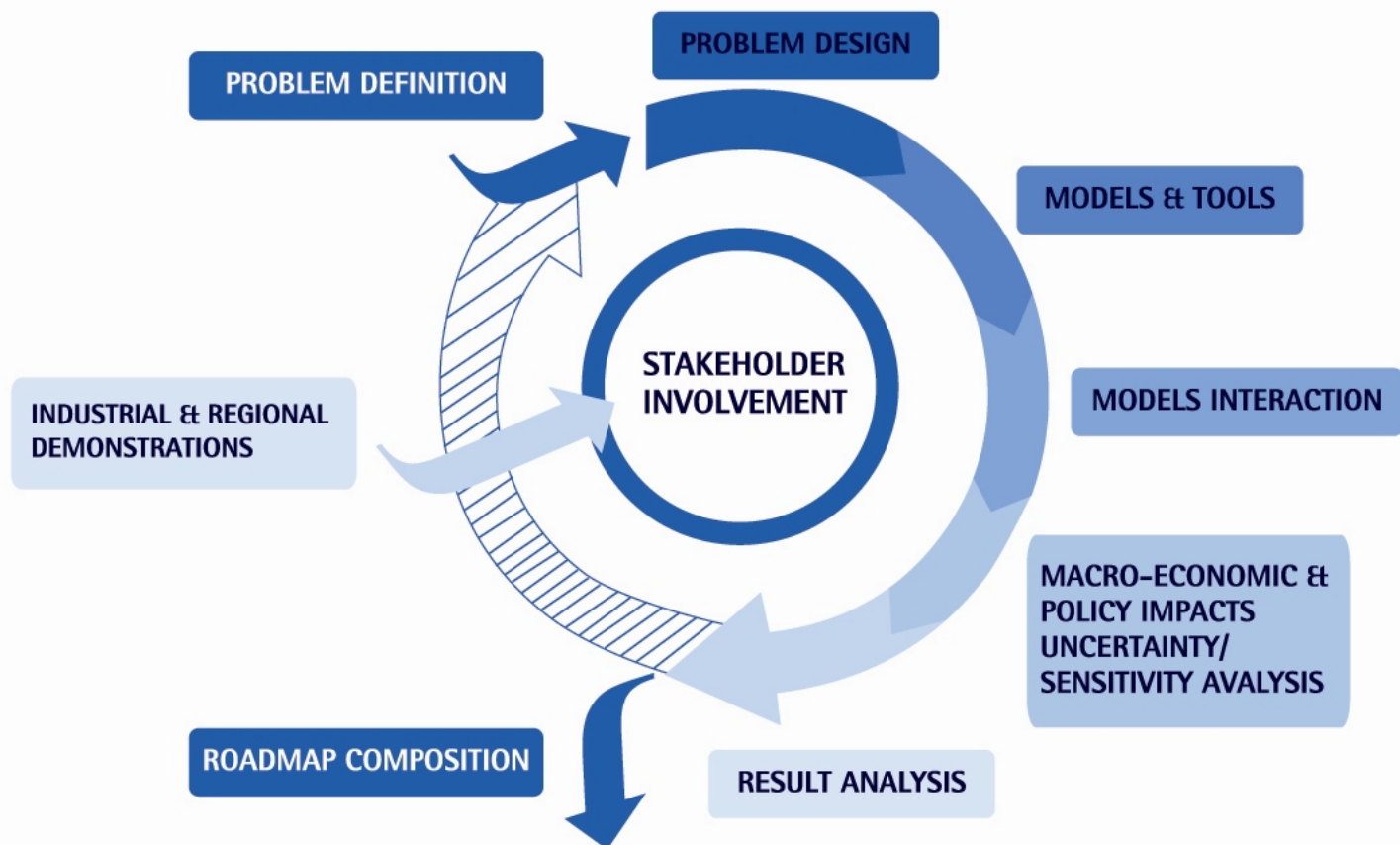
Resulting Documents

- US
 - Roadmap identifies key issues and challenges and potential for penetration
 - Posture Plan identifies DOE roles, activities, targets – Execution Plan
 - Available at <http://www.hydrogen.energy.gov/library.html>
- HyWays
 - Roadmap
 - Action plan
 - 2-page summary, executive summary, background documents, etc.
 - Available at <http://www.hyways.de/>

WP4: Dissemination

- Disseminate jointly developed understanding
- Workshops in other IPHE countries (e.g. China and Australia)
- Collect feedback from experts
- Further institutional & personal exchange
- **Current status:** Will be completed tomorrow (Jan-Oct 2008)

Proposed Roadmapping Process



Roadmapping Process

- Goal is to acquire answers on:
 - the technology portfolio and infrastructure build-up
 - Impact quantifications : Socio-Economic & Environmental
 - Policy support instruments
- Key reasoning processes
 - Problem definition - Structuring the analytical framework
 - Aims, scope and objectives of the analysis
 - Key-words: blue-print to kick-start, milestone based reasoning and refinement as analysis progresses
- Key operating processes
 - Models portfolio management
 - Stakeholder engagement, consultation, validation Process
 - Key-words: inputs/feedback/validation streams at each milestones

Recommendations for developing a roadmap

Assess your position in the global hydrogen development (early mover, fast follower, etc.) and according to that, develop realistic assumptions for hydrogen deployment of your region.

Incorporate your regional aspects (energy sources, policies, strengths of research and industry) into the activities.

Use appropriate models. Results must be comprehensible and robust; more sophisticated is not always better; model results are only valuable when inputs and approaches are accepted by the stakeholders.

For the assumptions with highest uncertainties (energy prices, hydrogen penetration levels), use imperfect foresight or do sensitivity analyses.
